



Rocky Mountain
National Park
Colorado

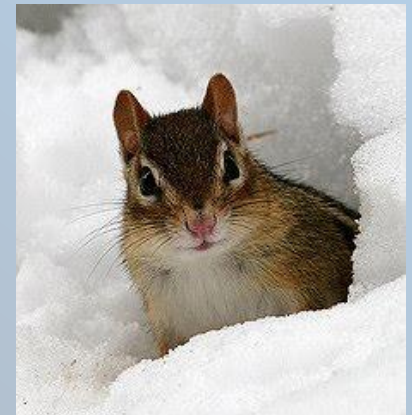
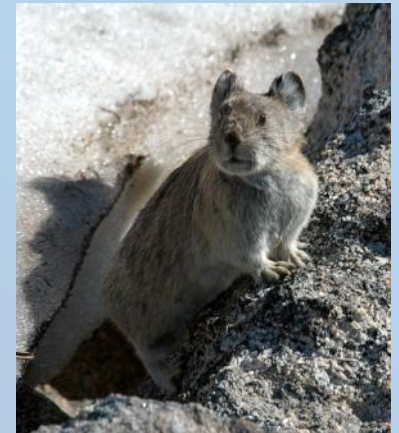
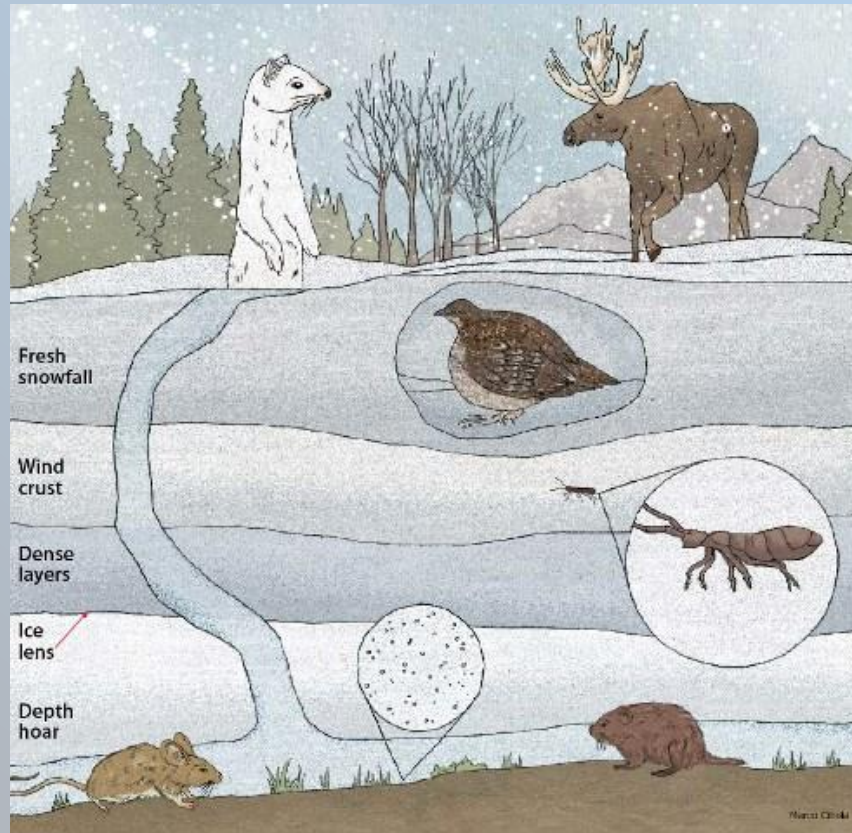


Glenn Patterson and Steven Fassnacht
Colorado State University
August 6, 2015

Trends in accumulation and melt of seasonal snow in Rocky Mountain National park



Snowpack provides winter habitat and protection for animals



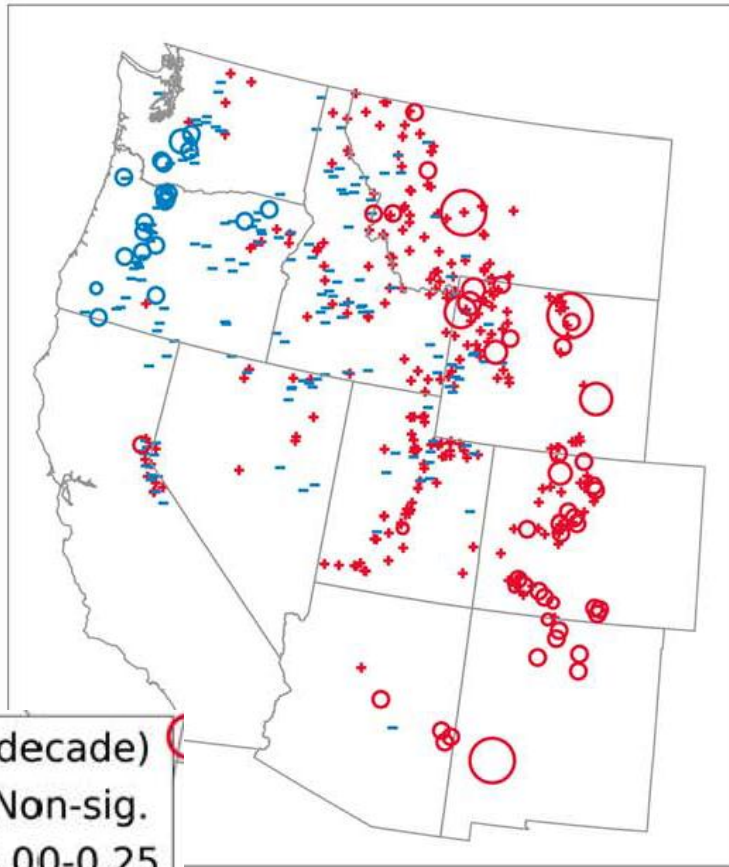




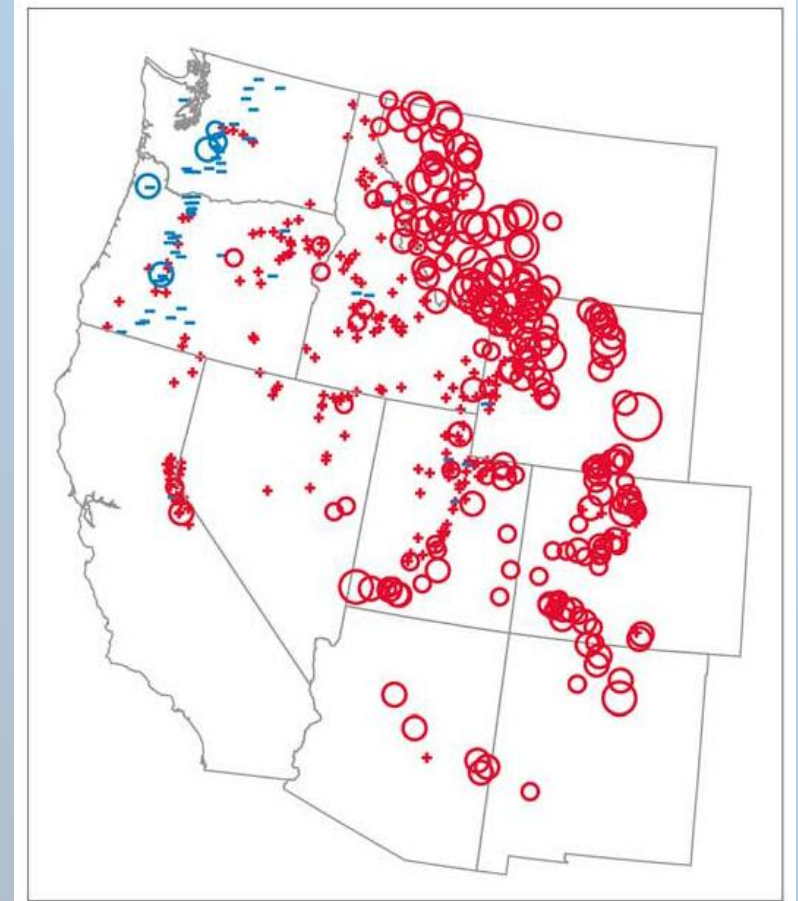
**Snowmelt runoff is key
to the hydrologic
regime.**

Temperatures have been rising

(b) SNOTEL Homogenized



Annual minimum temp



Annual maximum temp

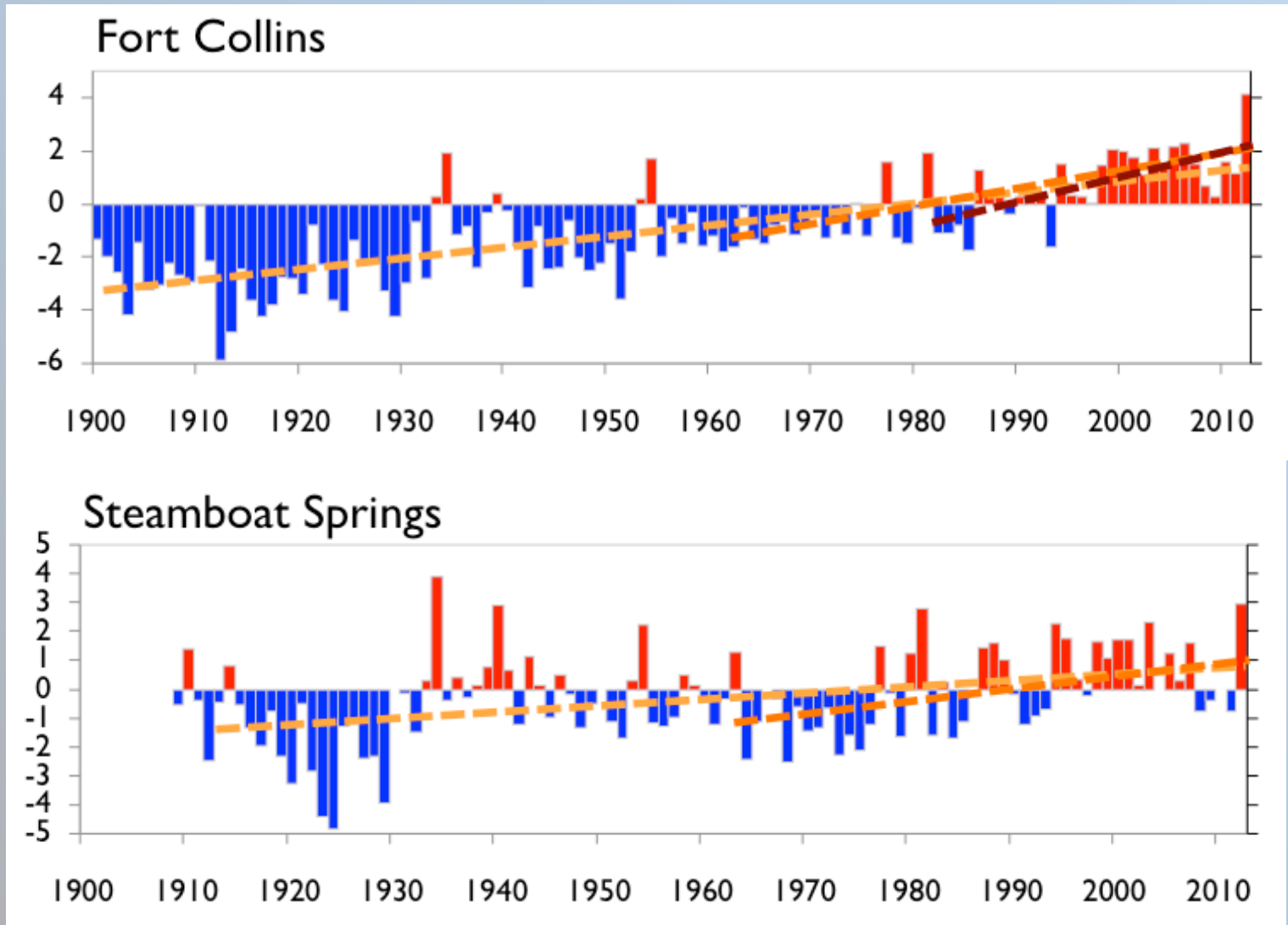
Trend (°C/decade)

- + - ± Non-sig.
- ±0.00-0.25
- ±0.25-0.50
- ±0.50-0.75
- ±0.75-1.00
- ±>1.00

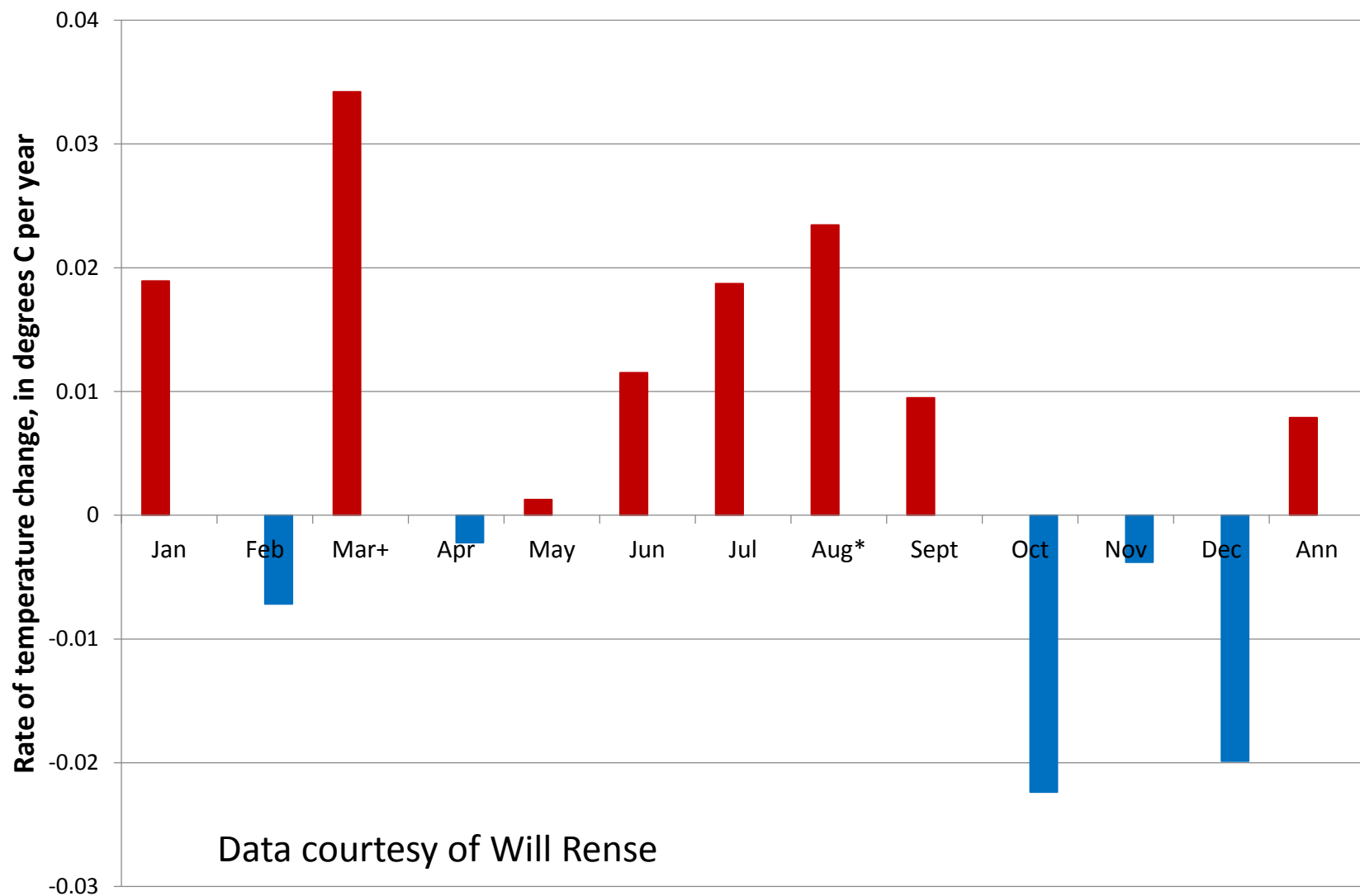
From Oyler et al, 2015.

Observed temperature trends

Departure from 1971-2000 average, degrees F



Trends in Average Temperature in Allenspark, by Month, 1960-2012



°F

0.072

0.054

0.036

0.018

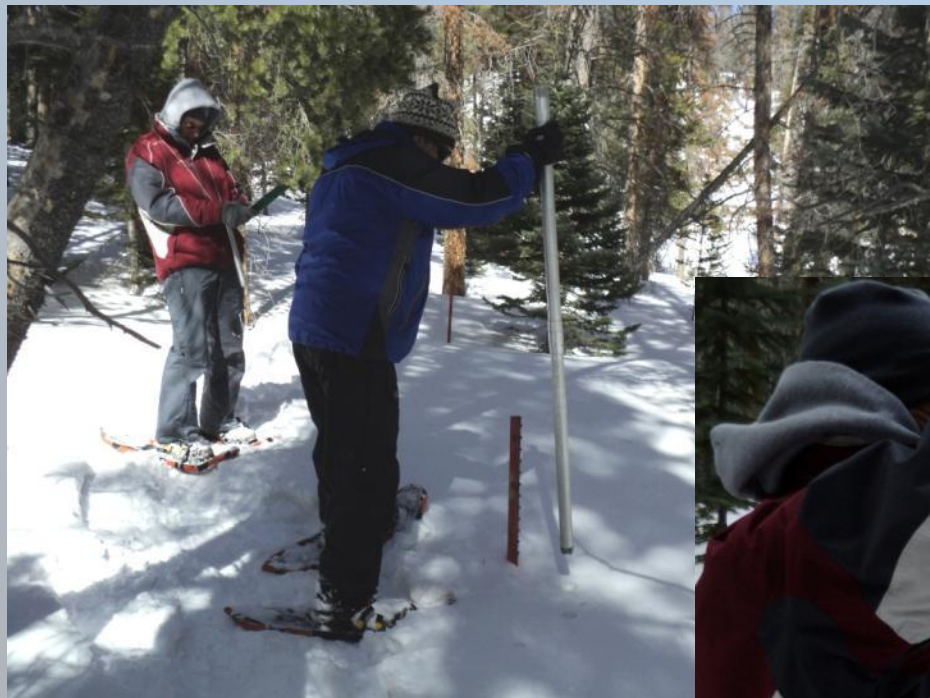
0

-0.018

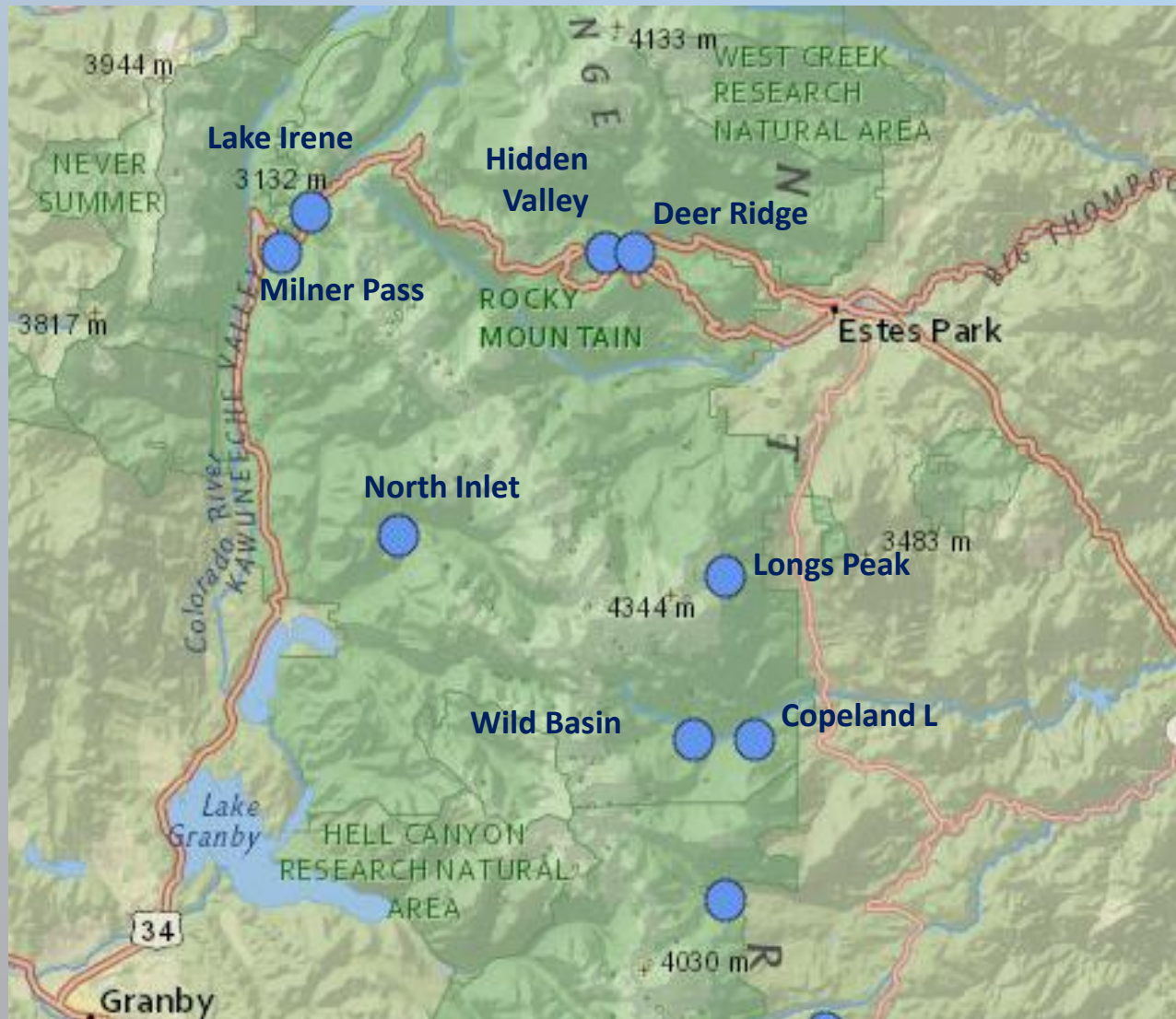
-0.036

-0.054

NRCS Snow course



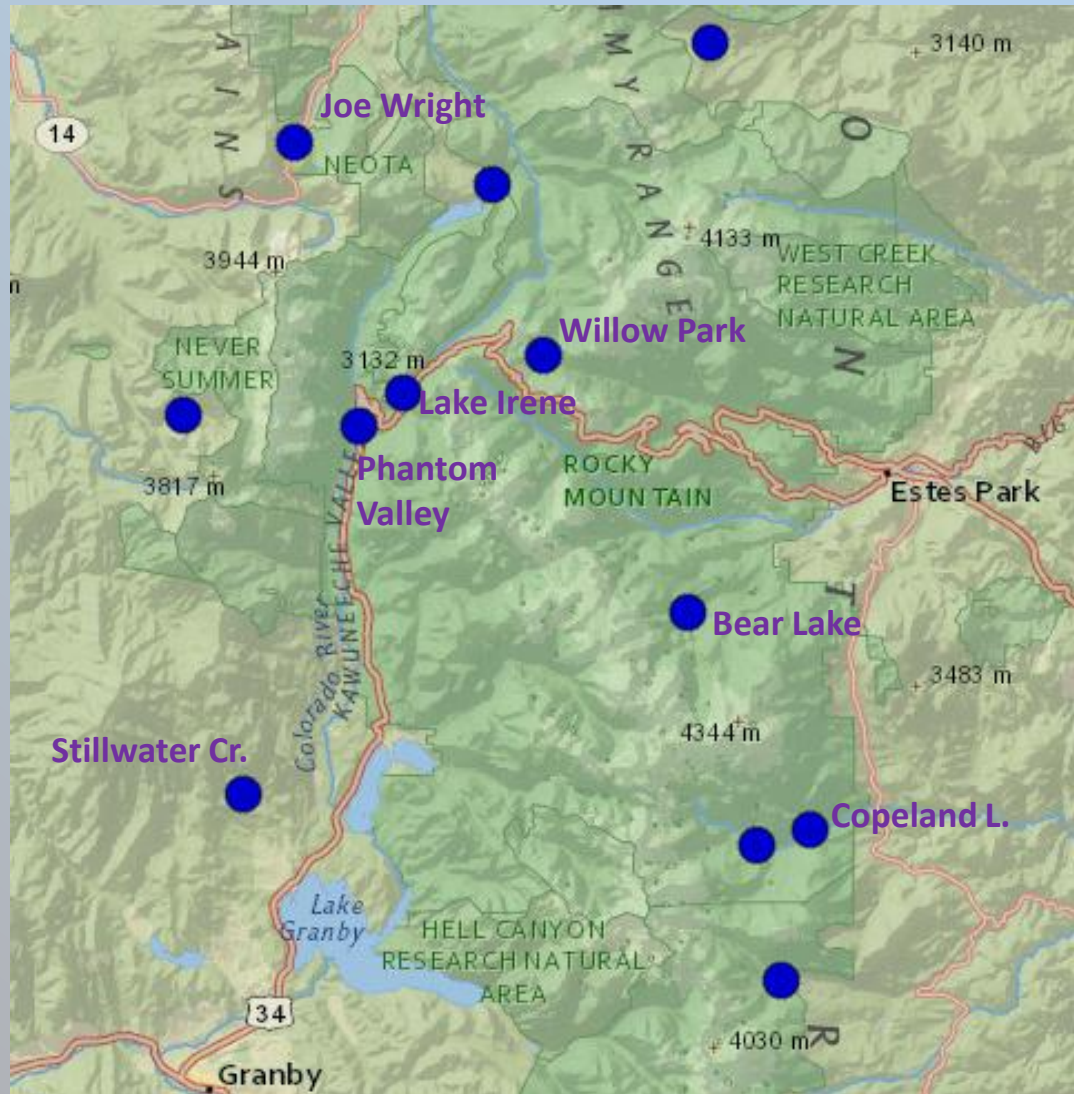
Snow courses in rocky Mountain NP



Snowpack telemetry (SNOTEL) station

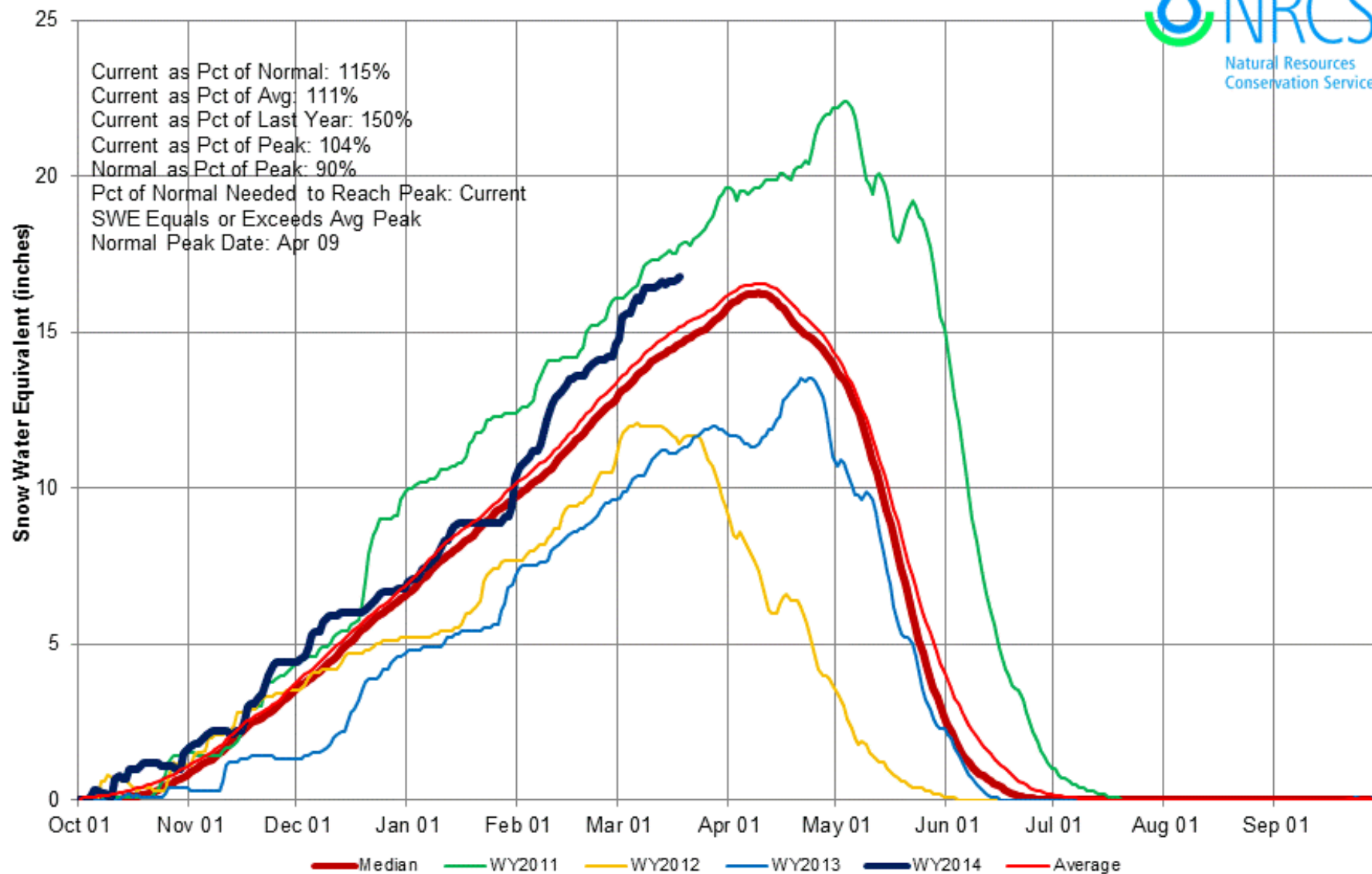


SNOTEL Stations in and Near Rocky

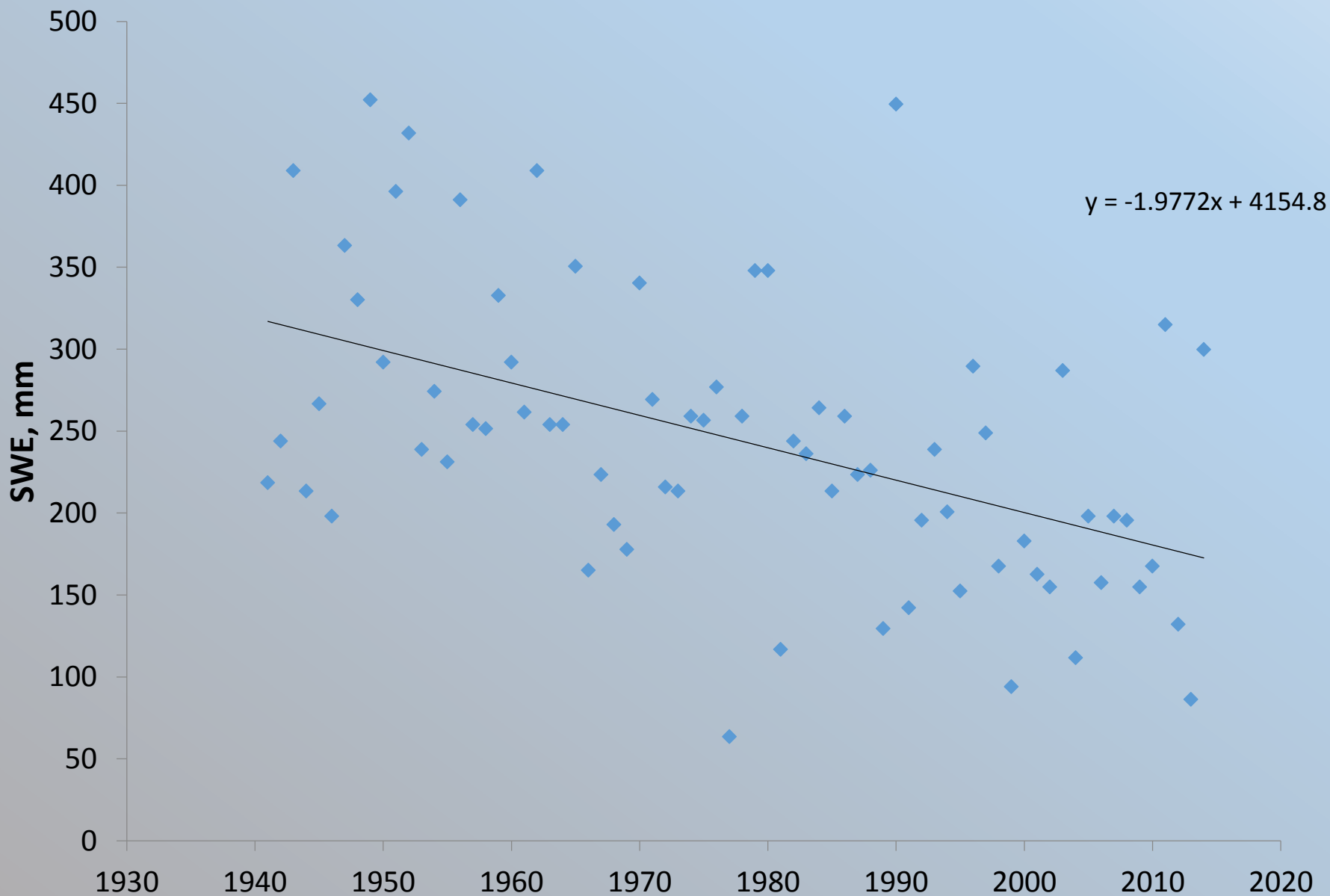


Colorado State-Wide Time Series Snowpack Summary

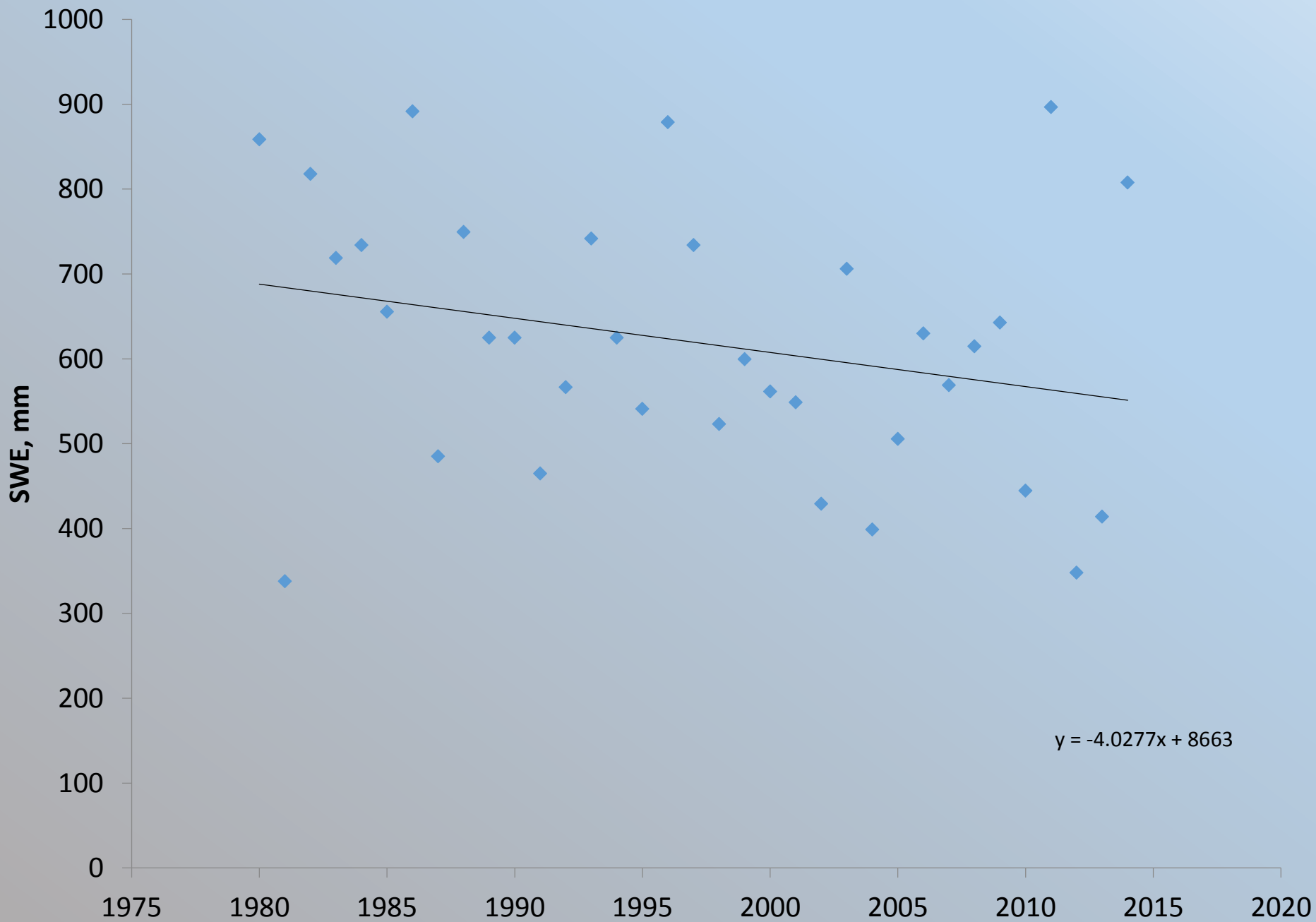
Based on Provisional SNOTEL data as of Mar 18, 2014



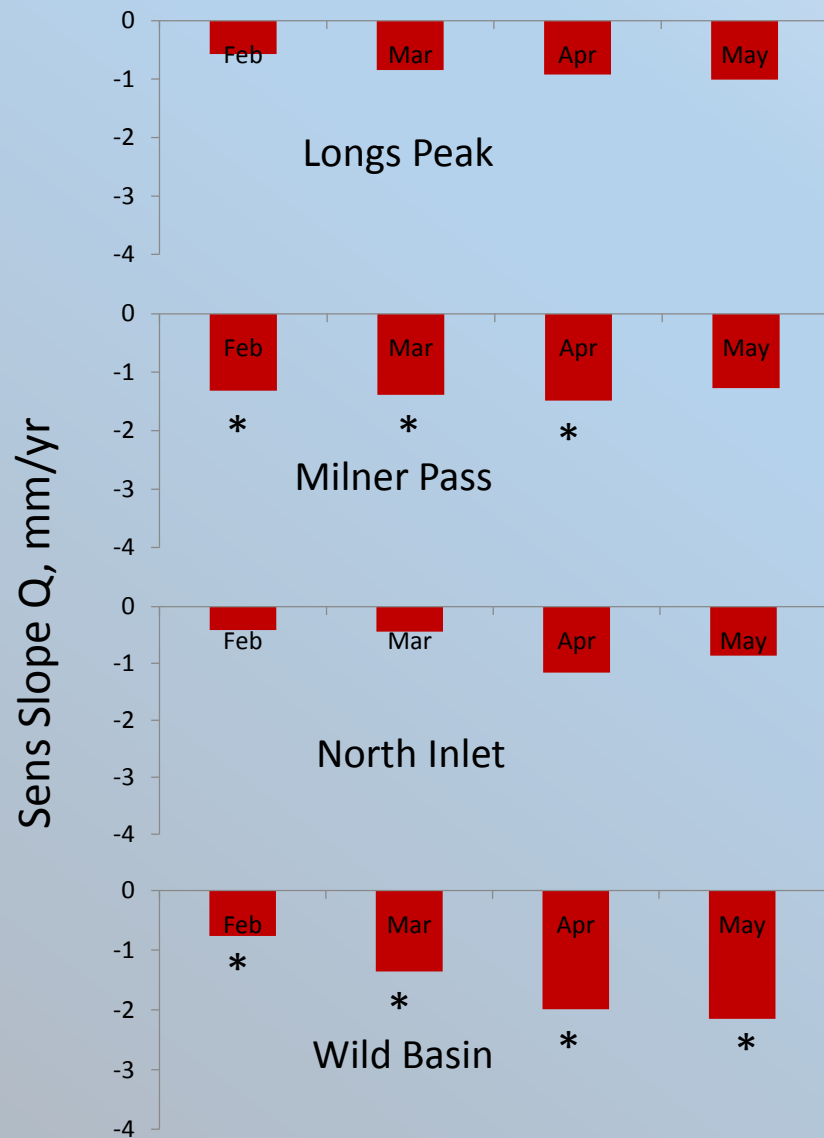
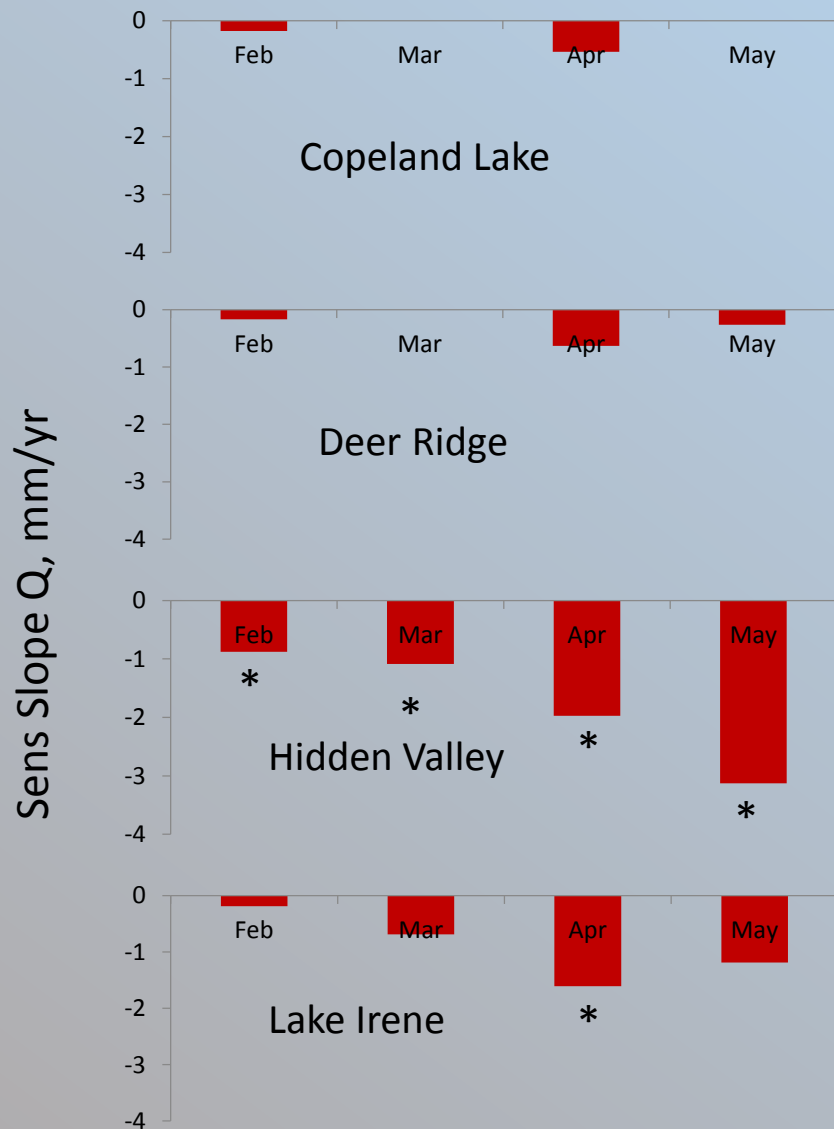
Hidden Valley Snow Course April 1 SWE 1941-2014



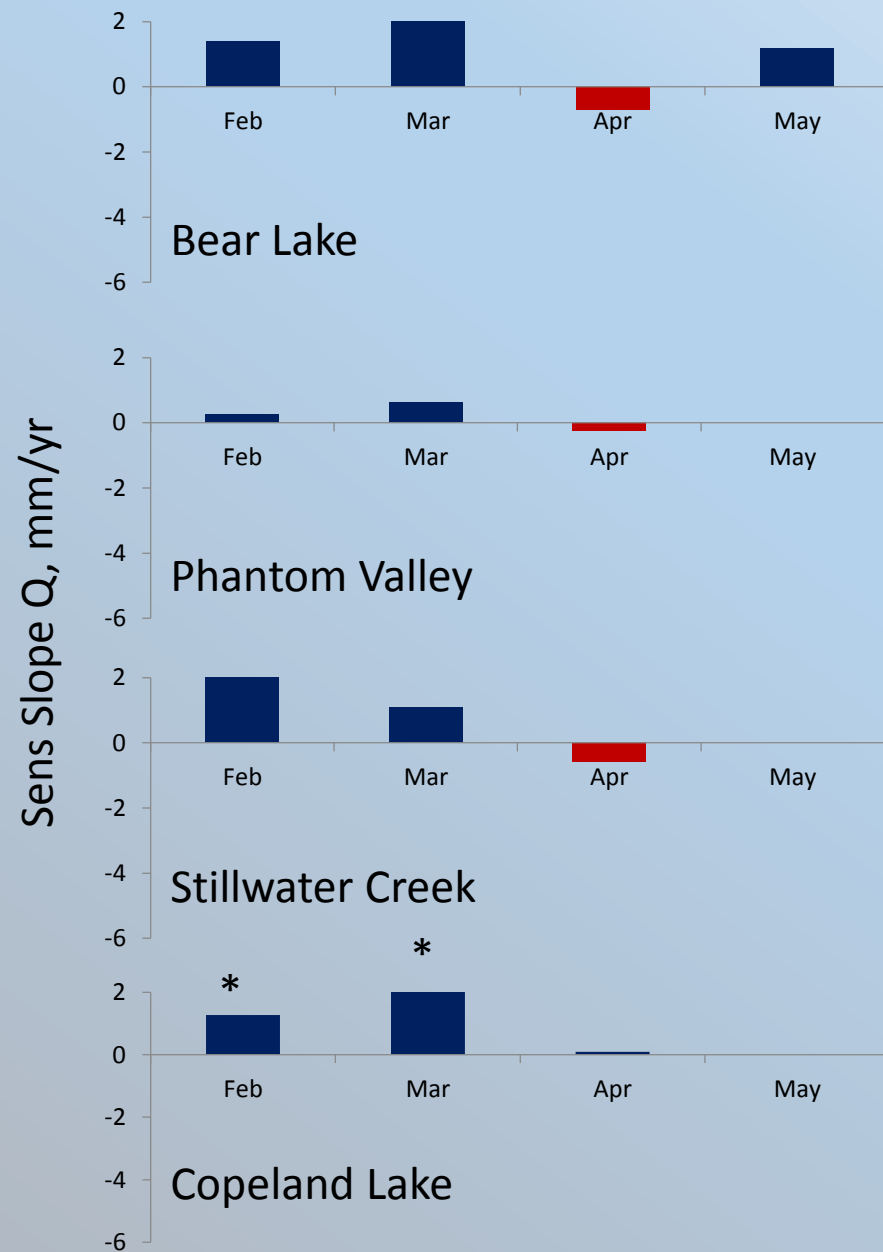
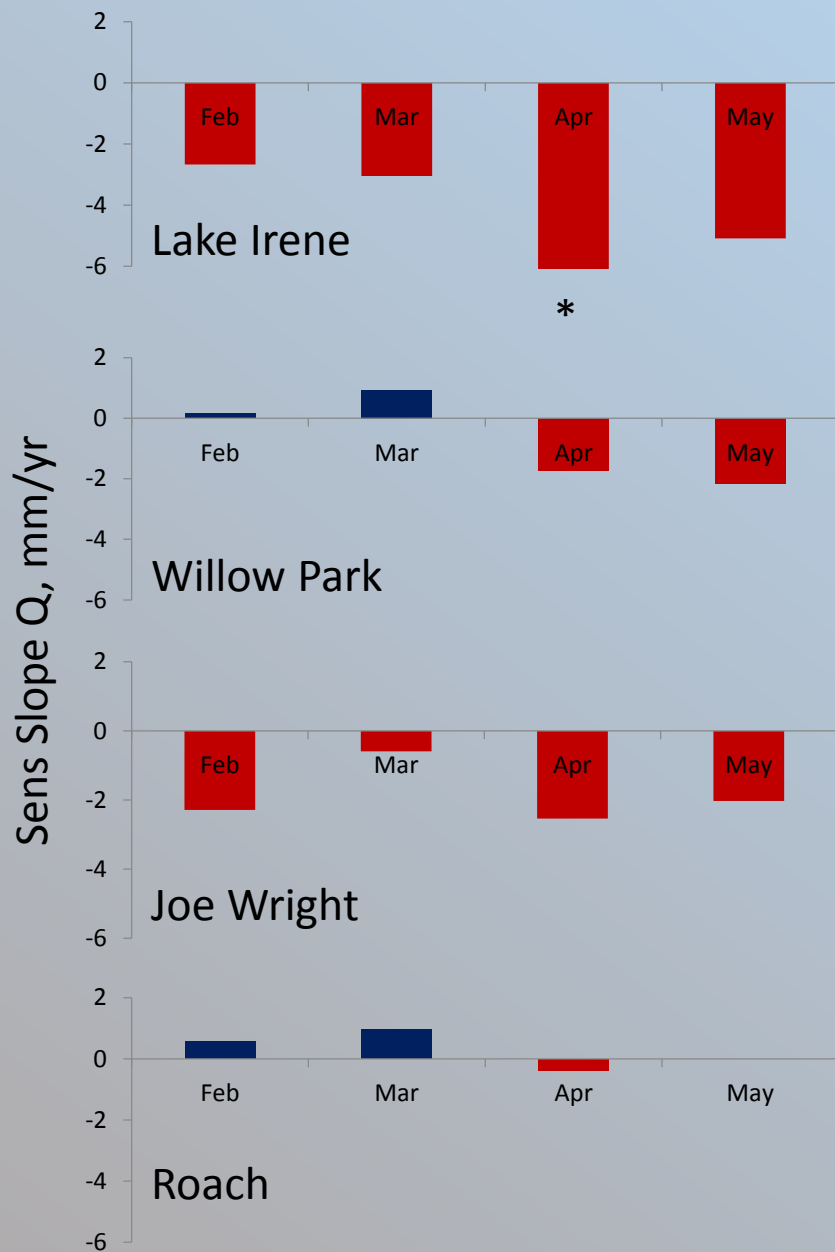
Lake Irene SNOTEL April 1 SWE



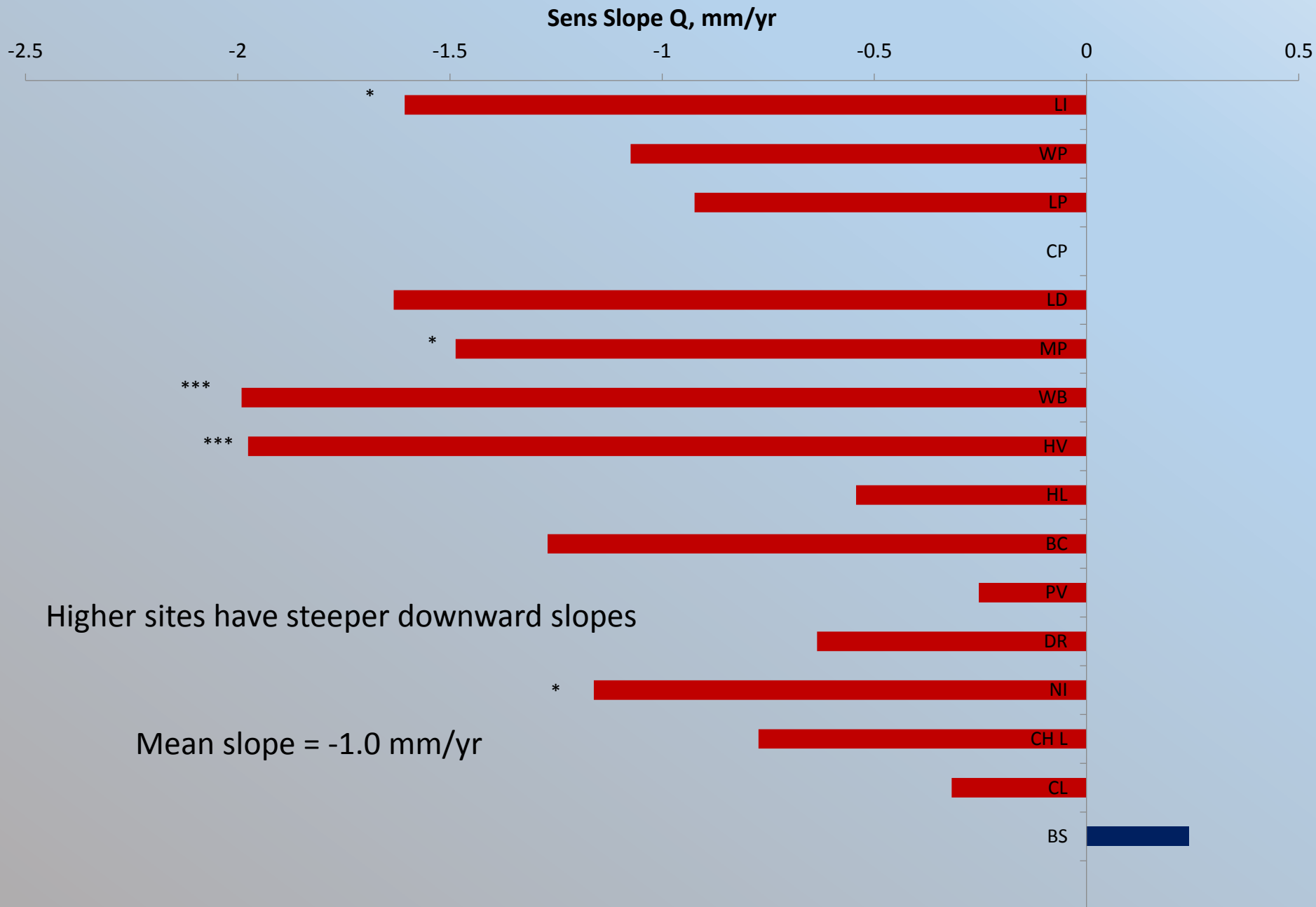
Slopes of Trends in Snow Course SWE Data, 1938-2014



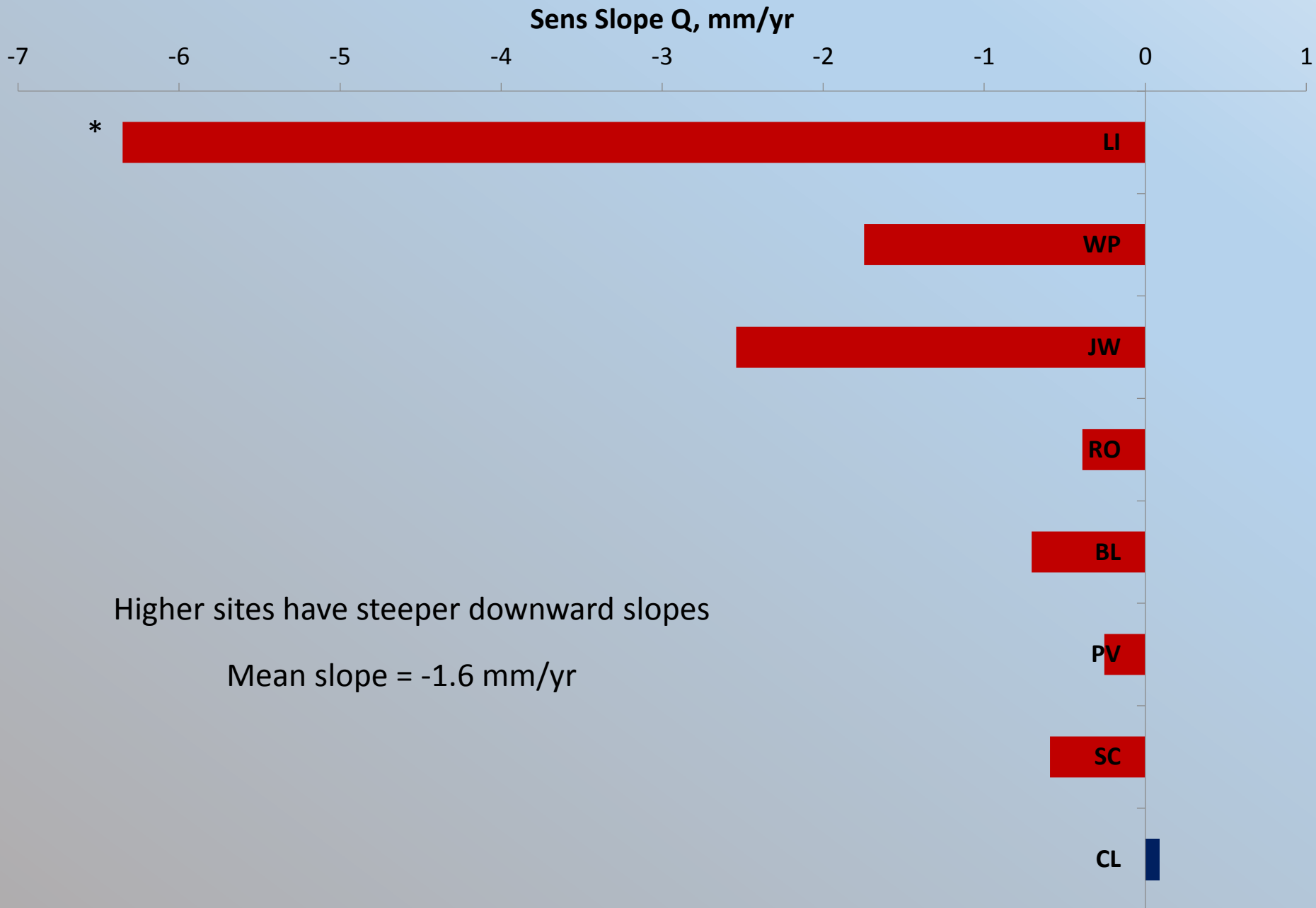
Slopes in Trends of SNOTEL SWE Data, 1980-2014



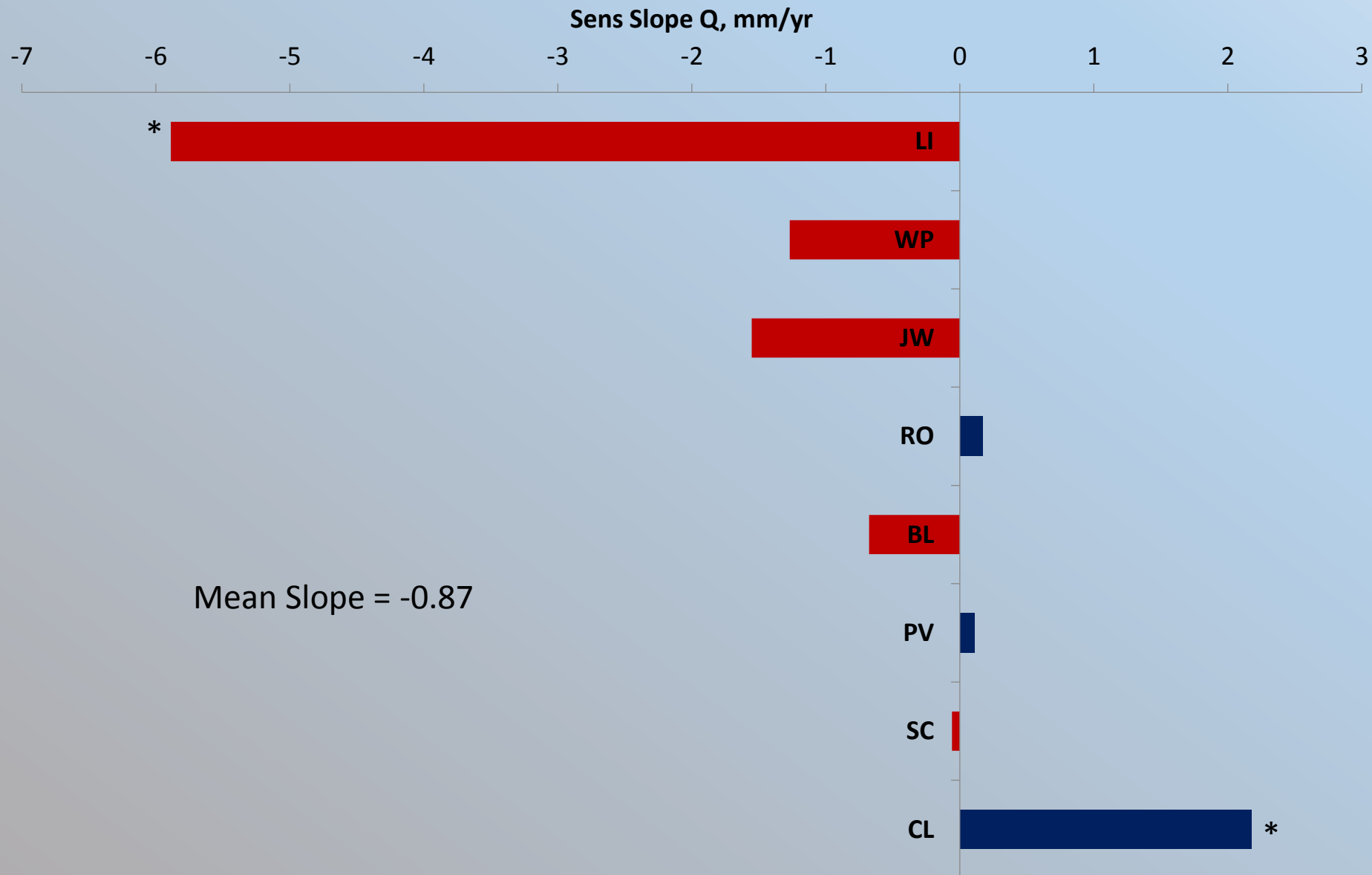
Slope of Trend Line for April 1 SWE at Snow Courses, 1938-2014



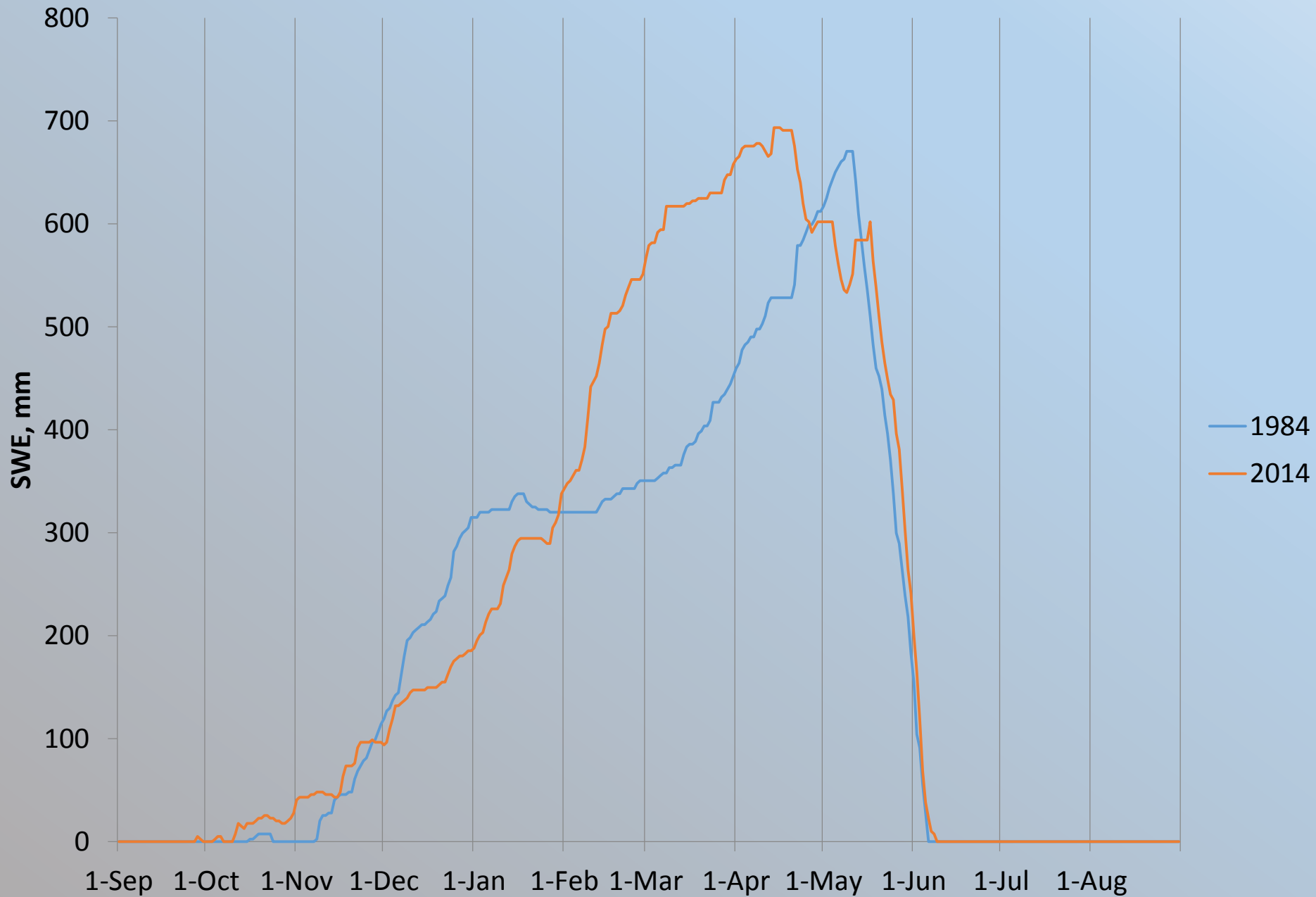
Slope of Trend Line for April 1 SWE at SNOTELS, 1980-2014



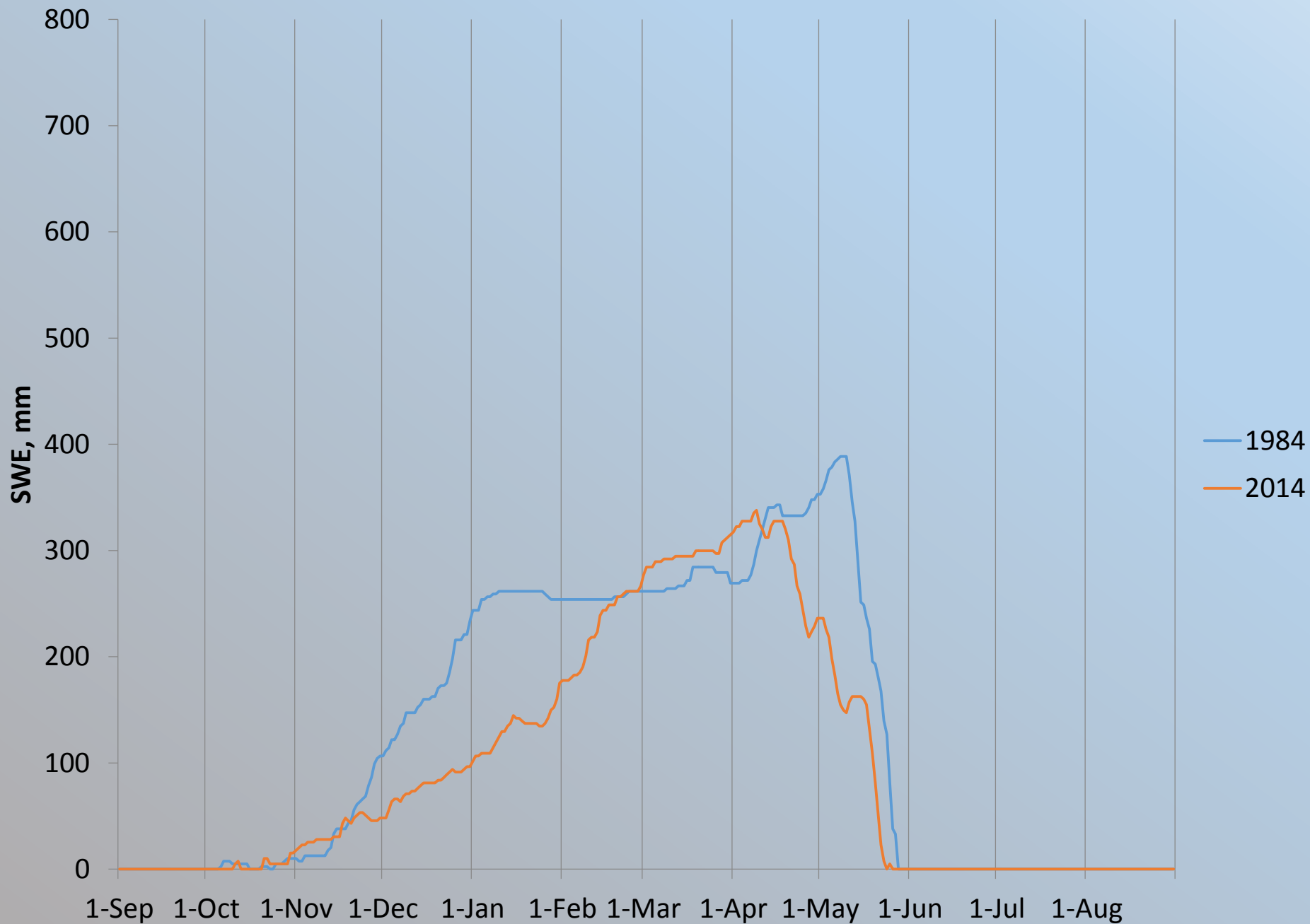
Slope of Trend Line for Peak SWE at SNOTELS, 1980-2014



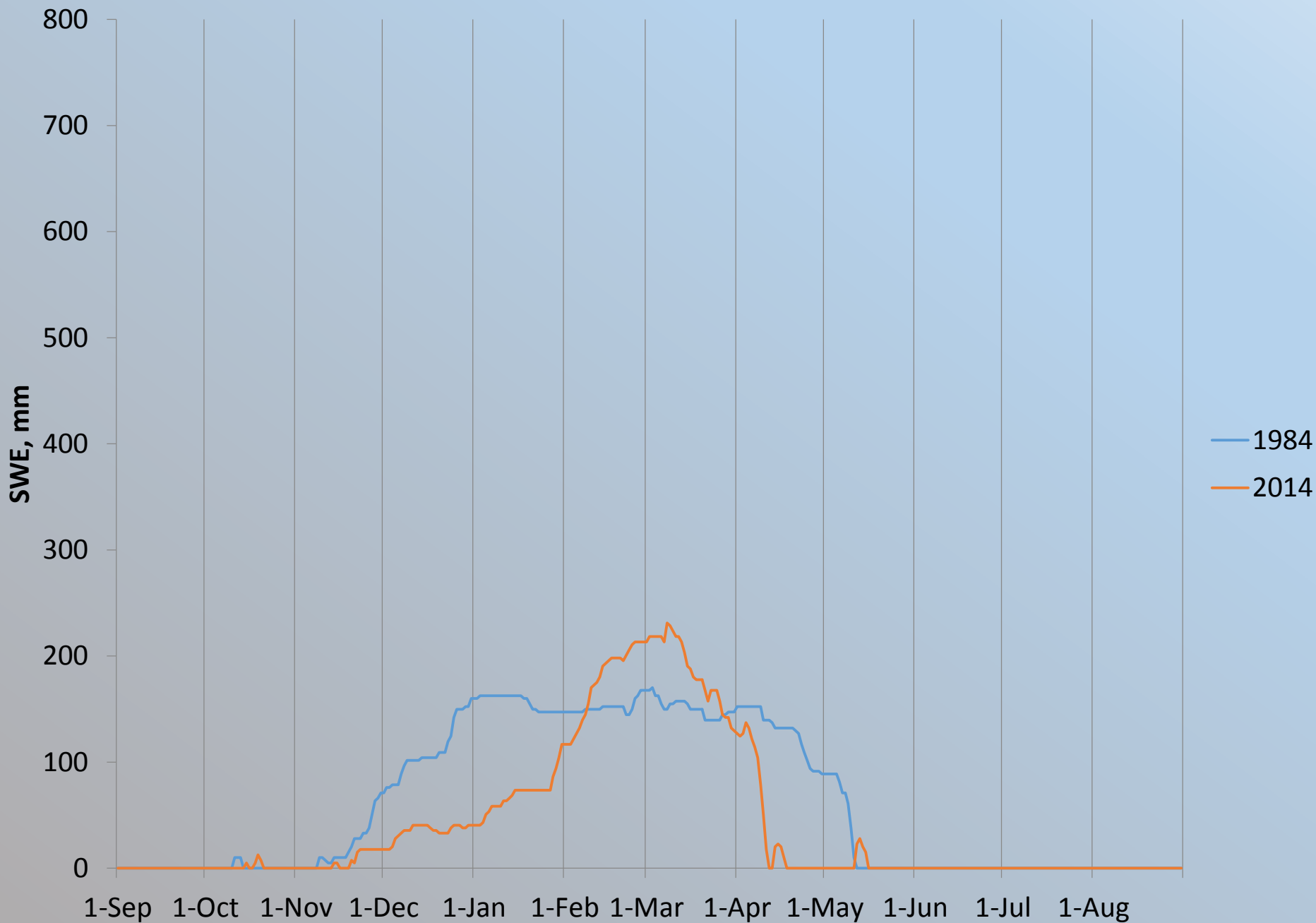
Bear Lake SWE



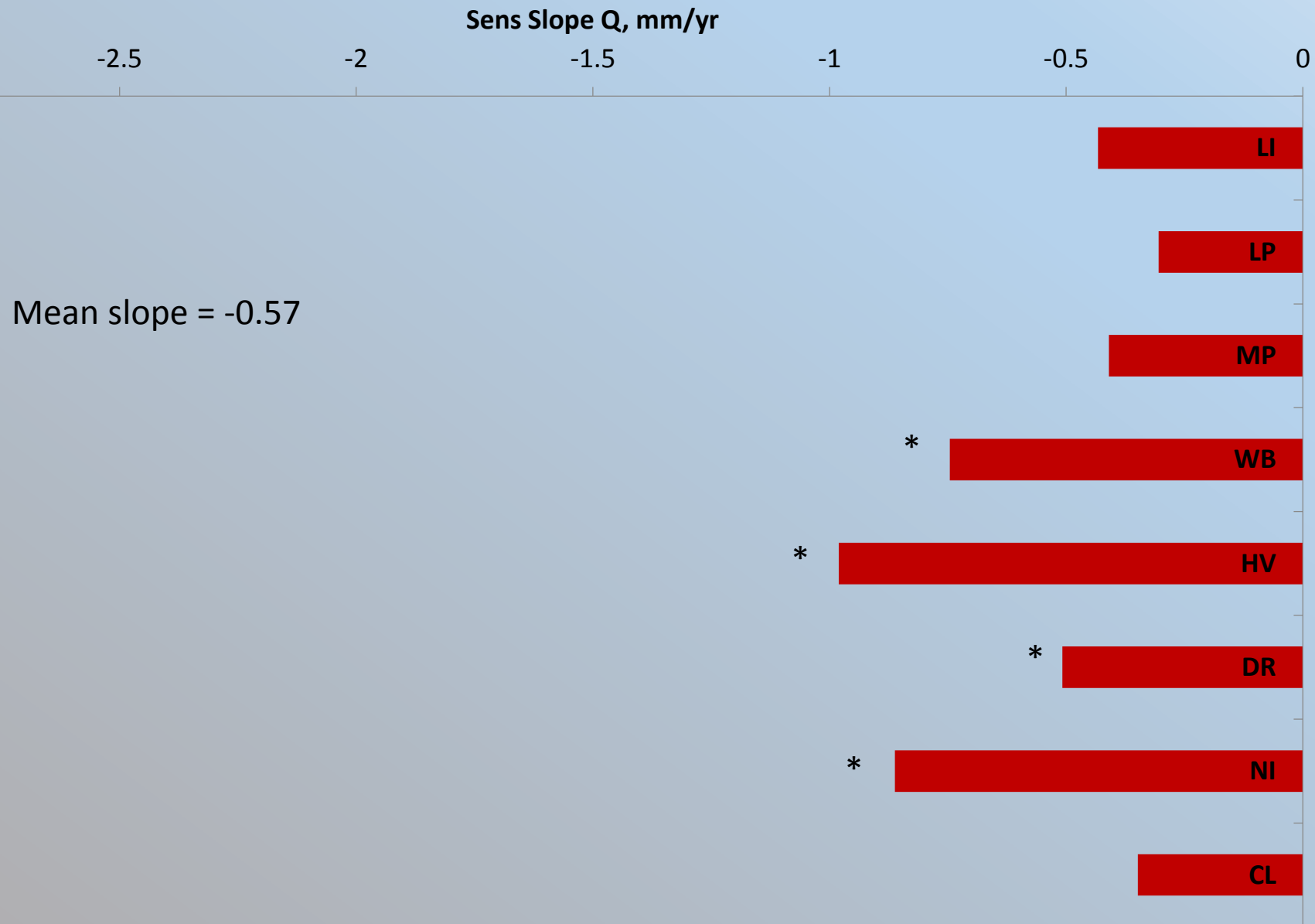
Phantom Valley SWE



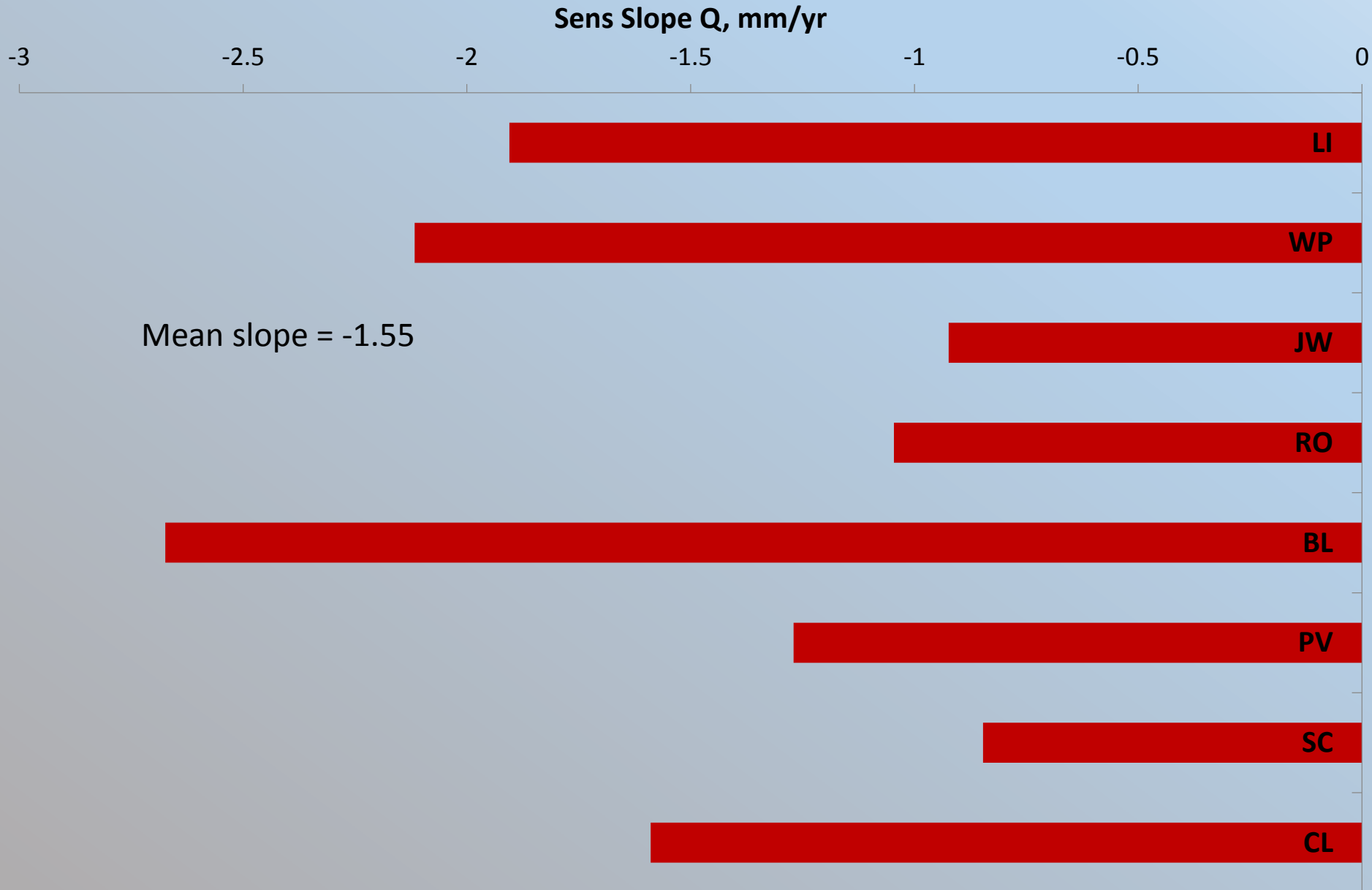
Copeland Lake SWE



Slope of Trend Line for March Change in SWE at Snow Courses, 1938-2014



Slope of Trend Line for March Change in SWE at SNOTELS, 1980-2014

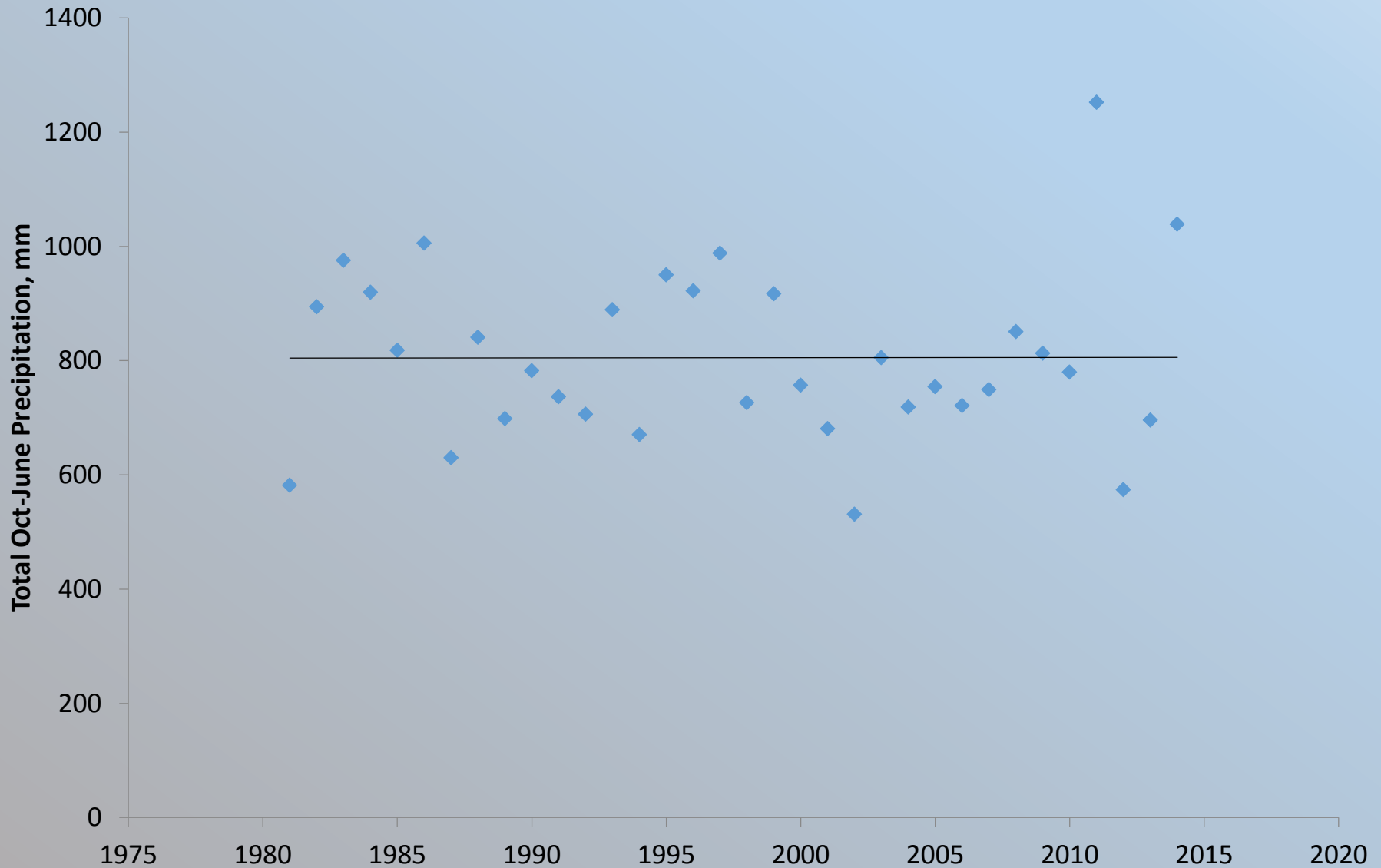


What do the downward trends mean?

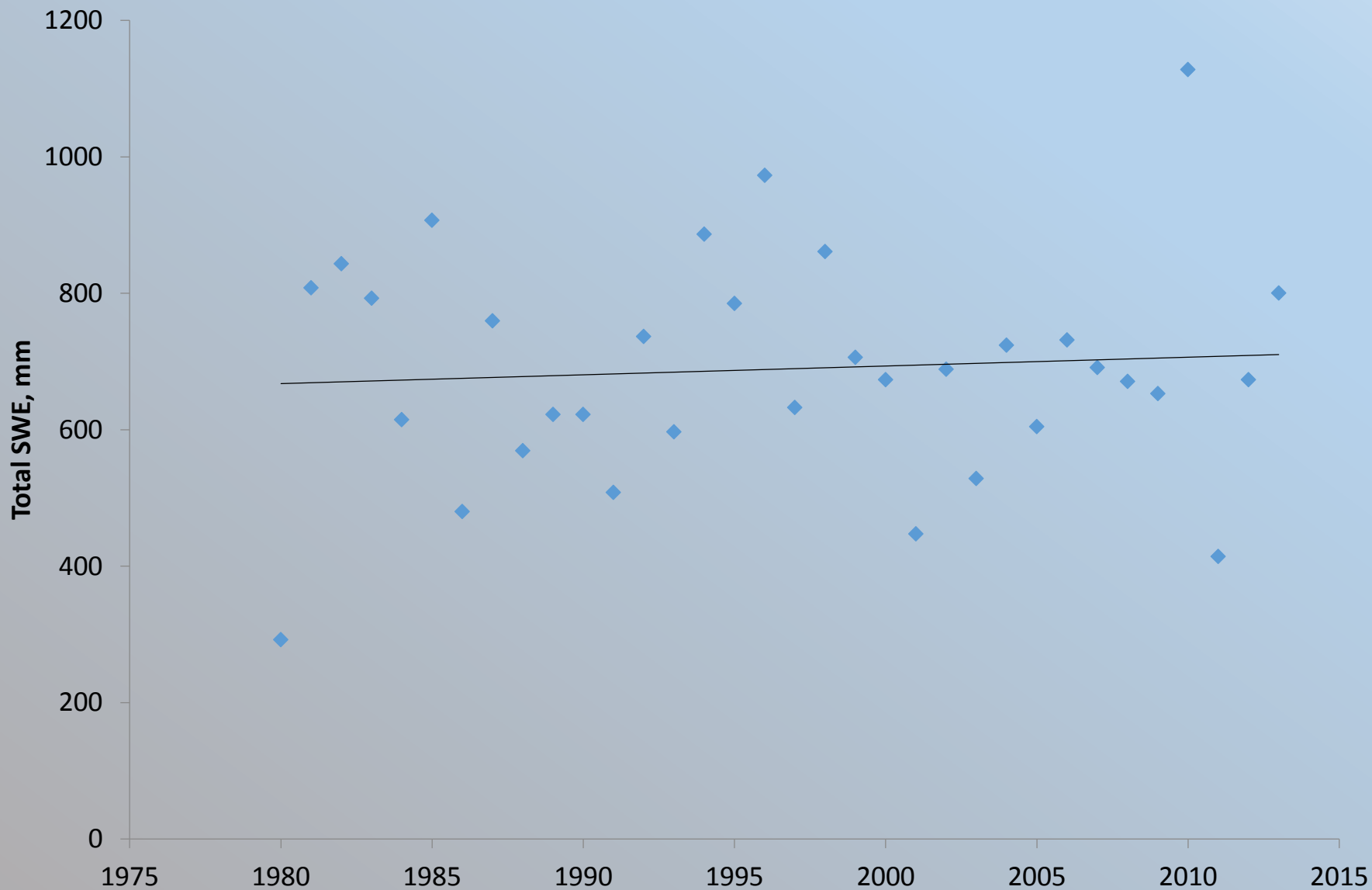
- Less total cold-season precipitation?
- Less snow falling, and more rain?
- More Evapotranspiration?
- Something else?



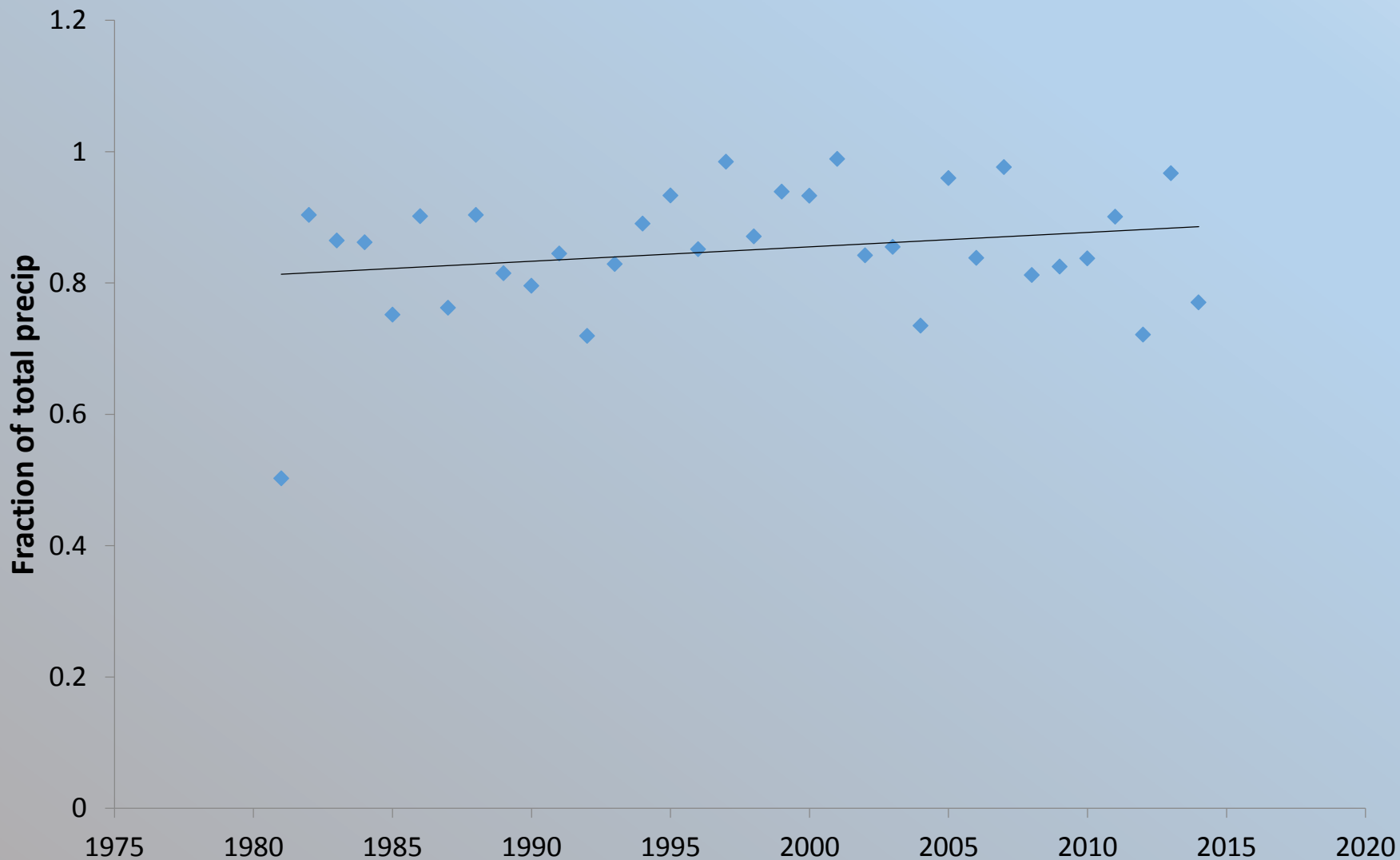
Willow Park SNOTEL Total Oct-June Precipitation 1981-2014



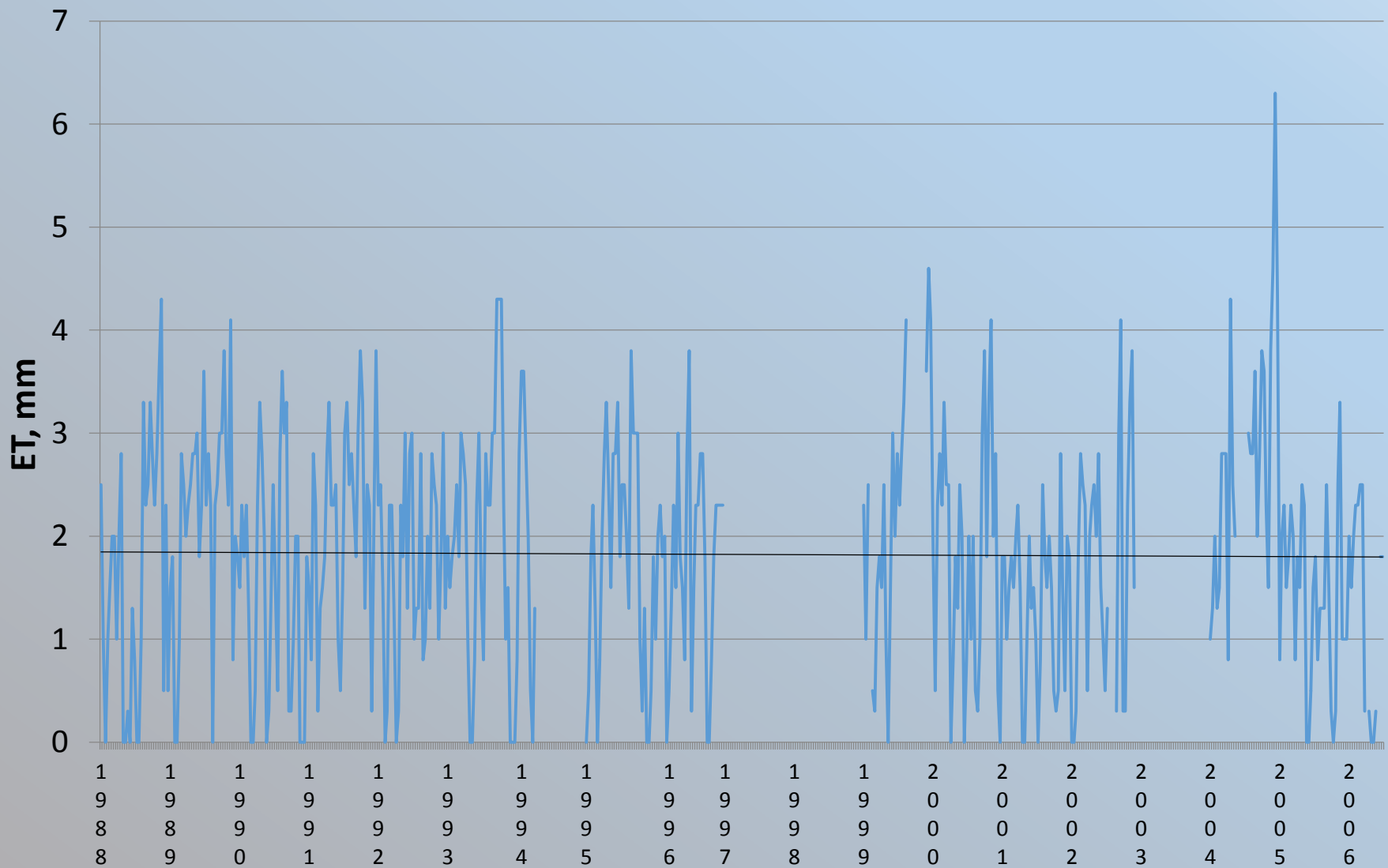
Willow Park SNOTEL Total SWE 1981-2014



Willow Park SNOTEL Total SWE as fraction of Total Oct-June Precip 1981-2014



Niwot Ridge A-1 March ET, mm/day (2195 m)



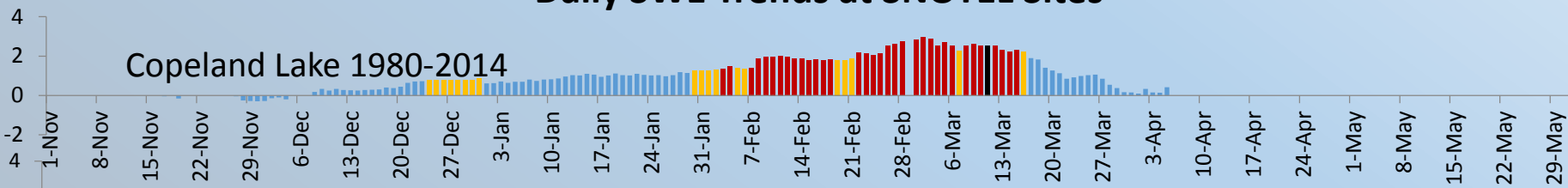
So...

- Total cold-season precipitation is consistent.
- Total SWE as a proportion of total cold-season precipitation is consistent.
- ET is consistent.
- SNOTEL data allow us to see what's happening on a daily basis, so what can we learn from that?



Daily SWE Trends at SNOTEL Sites

Copeland Lake 1980-2014



Lake Irene 1980-2014



Bear Lake 1981-2014



Willow Park 1981-2014



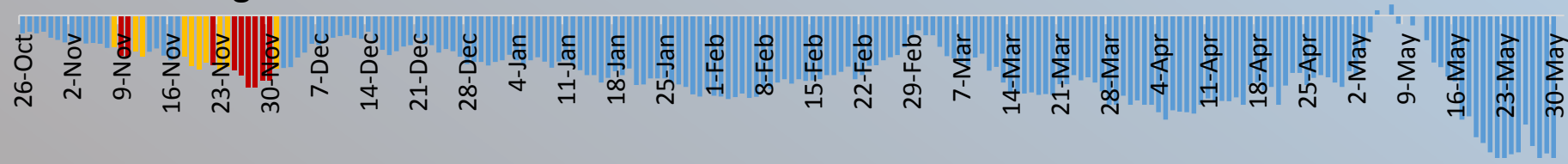
Phantom Valley 1981-2014

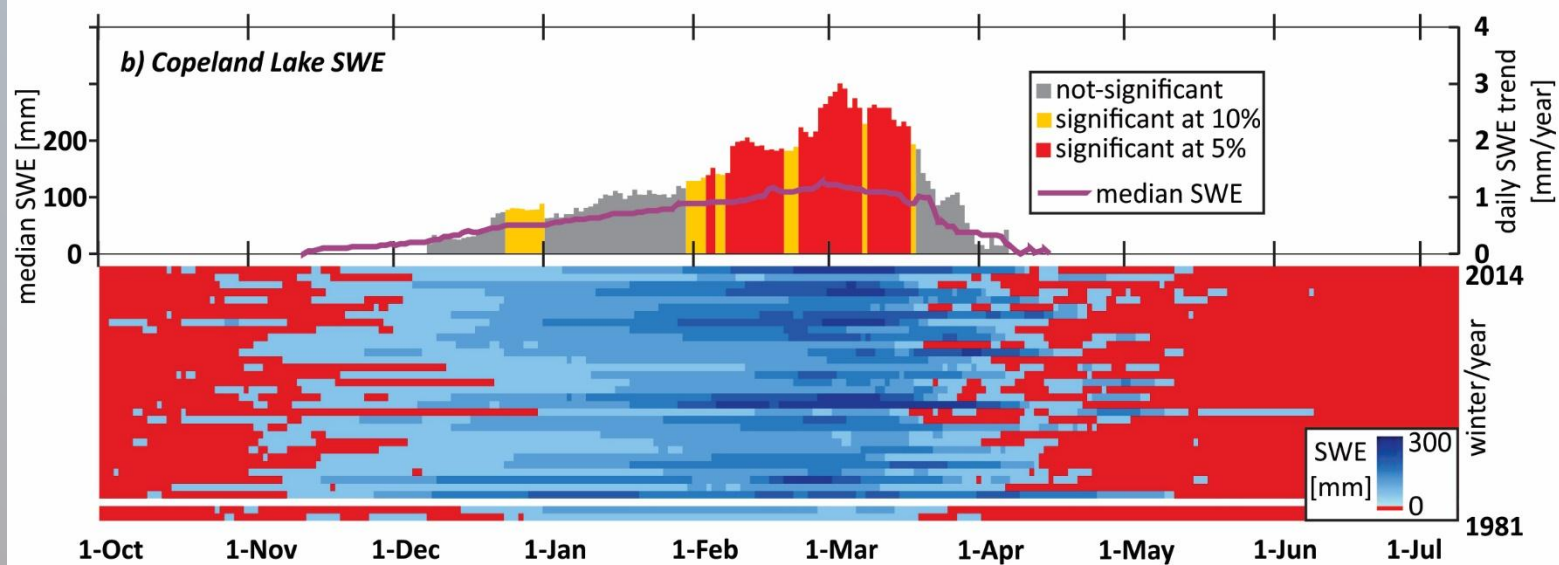
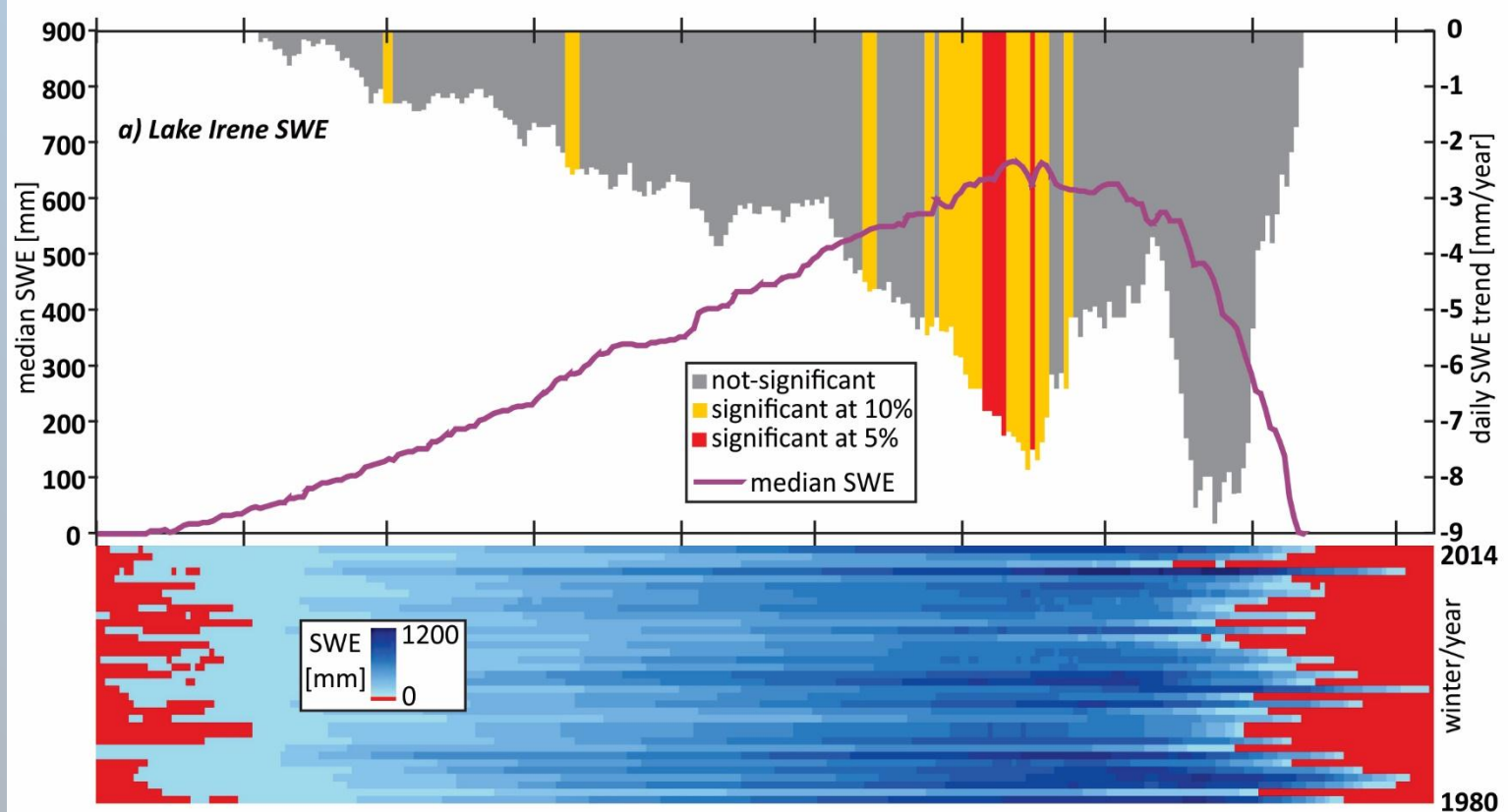


Stillwater Creek 1986-2014



Joe Wright 1980-2014

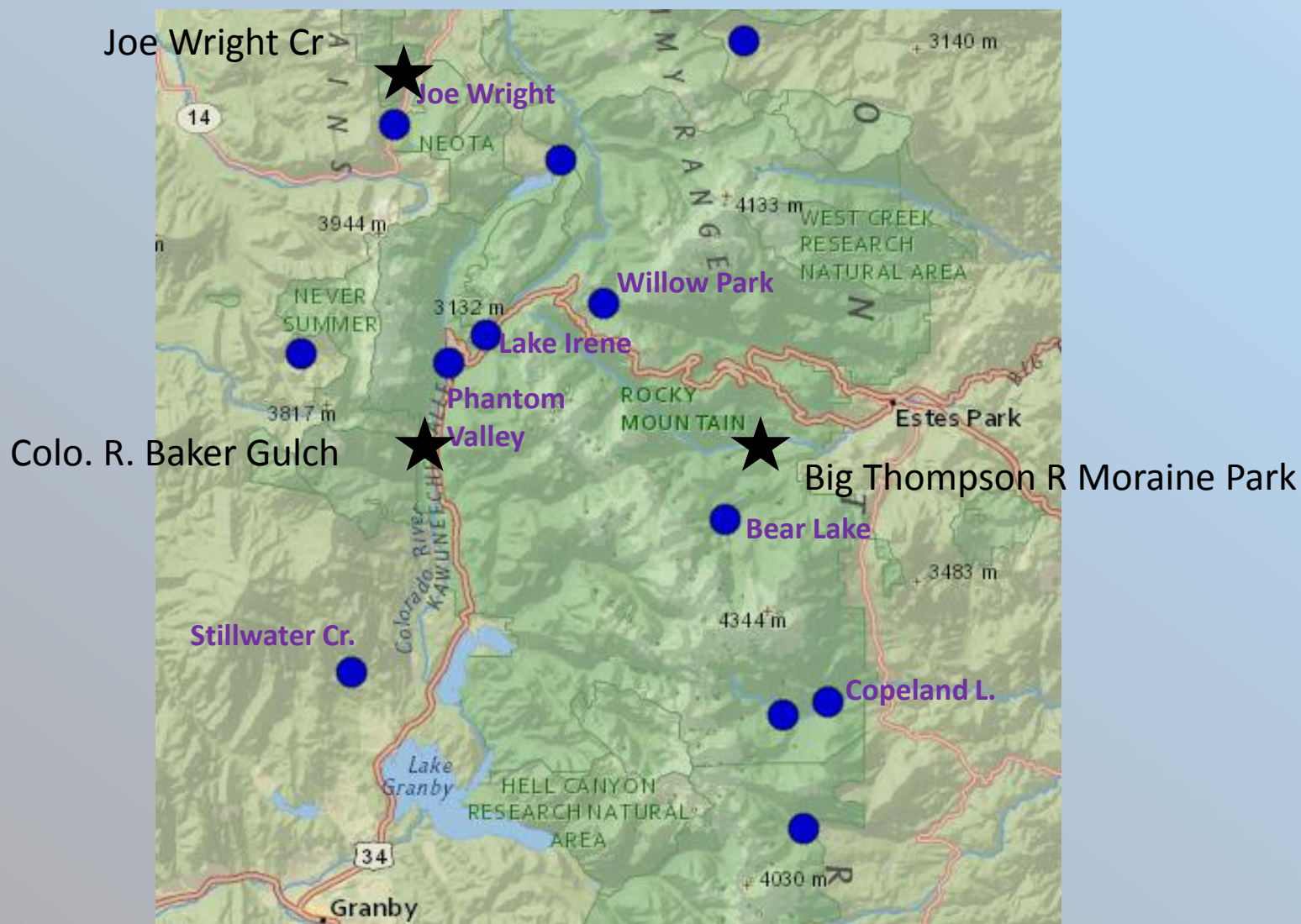




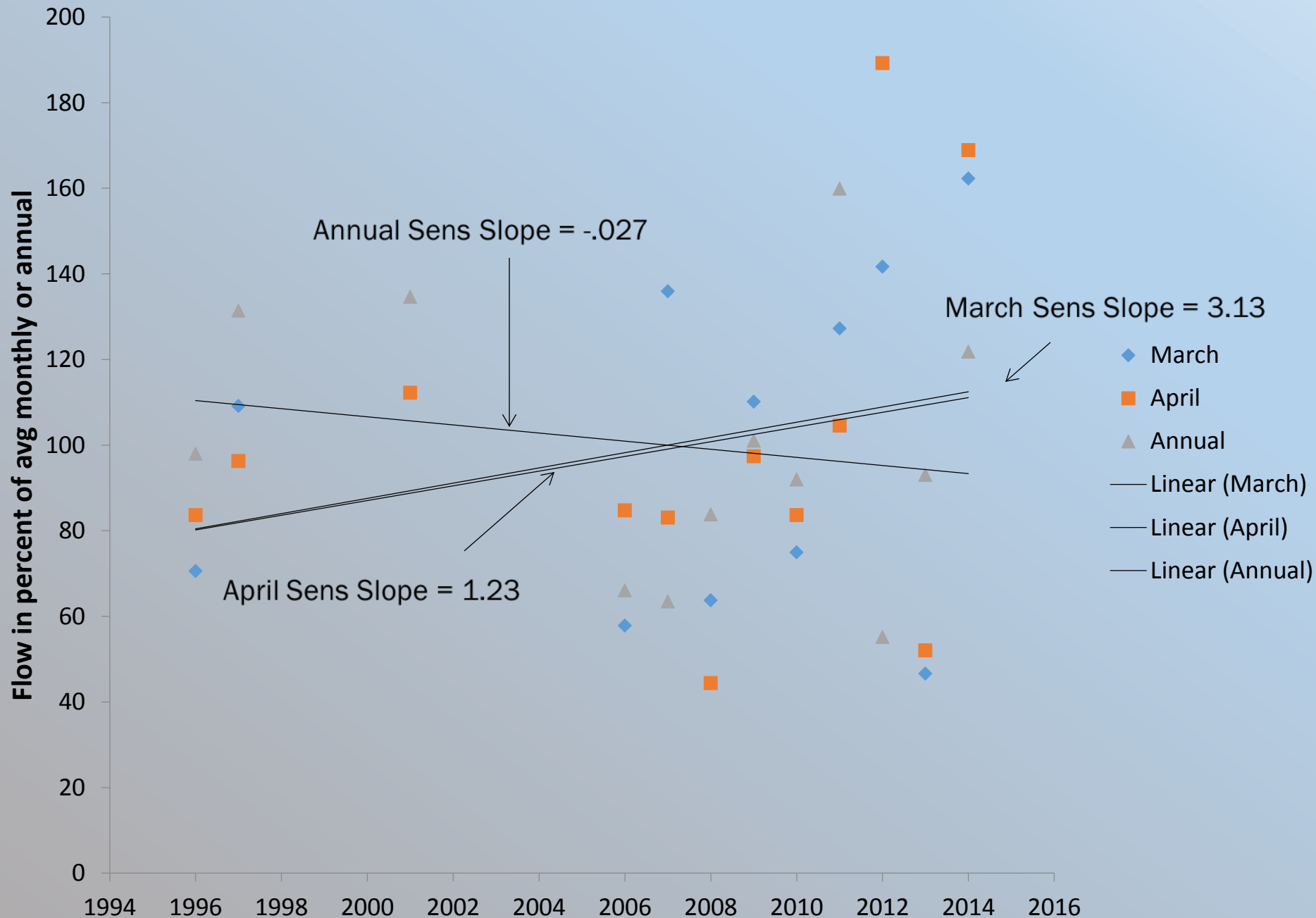
Does the loss of SWE in March-April show up as streamflow?



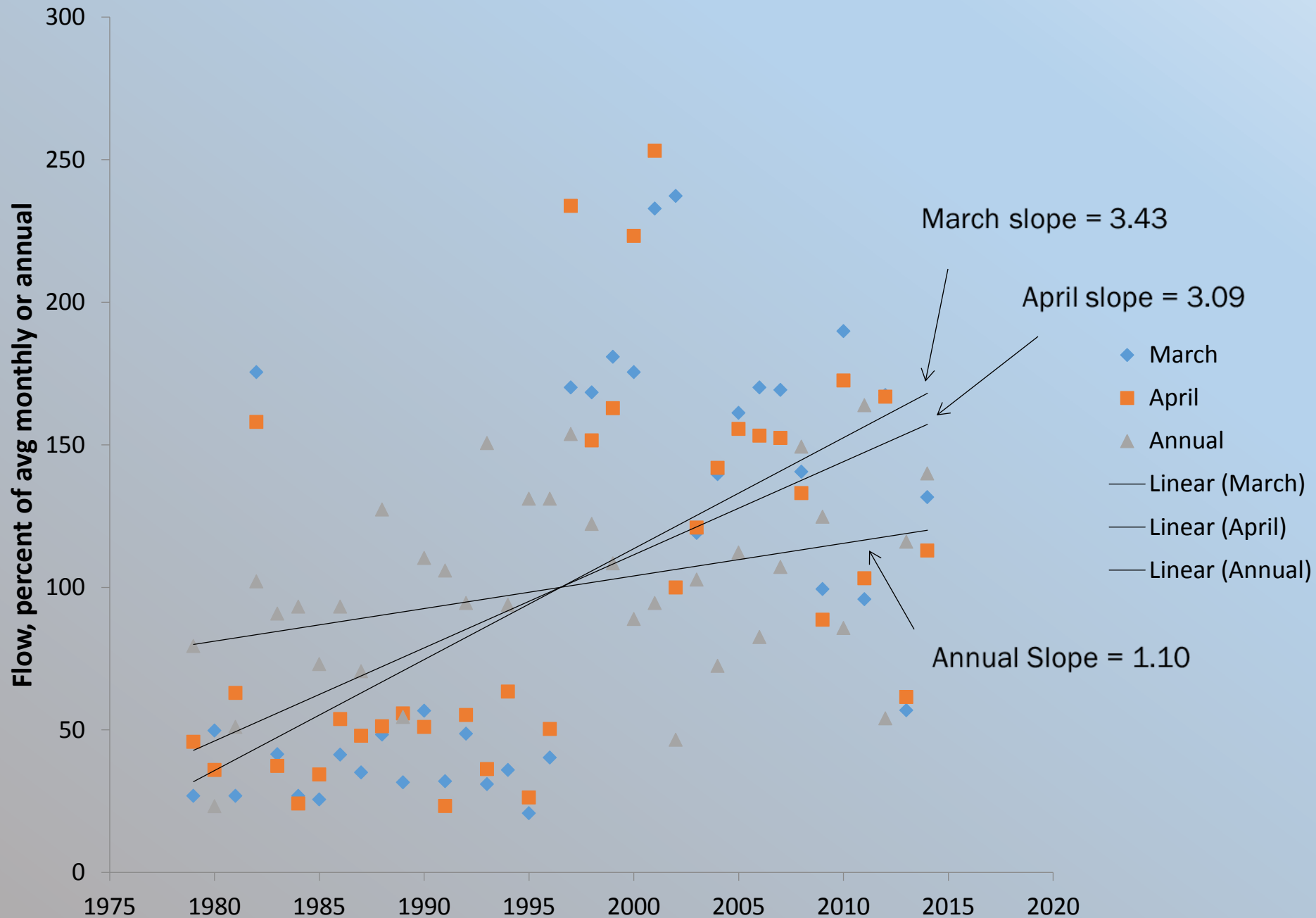
Stream gauges near the snotels



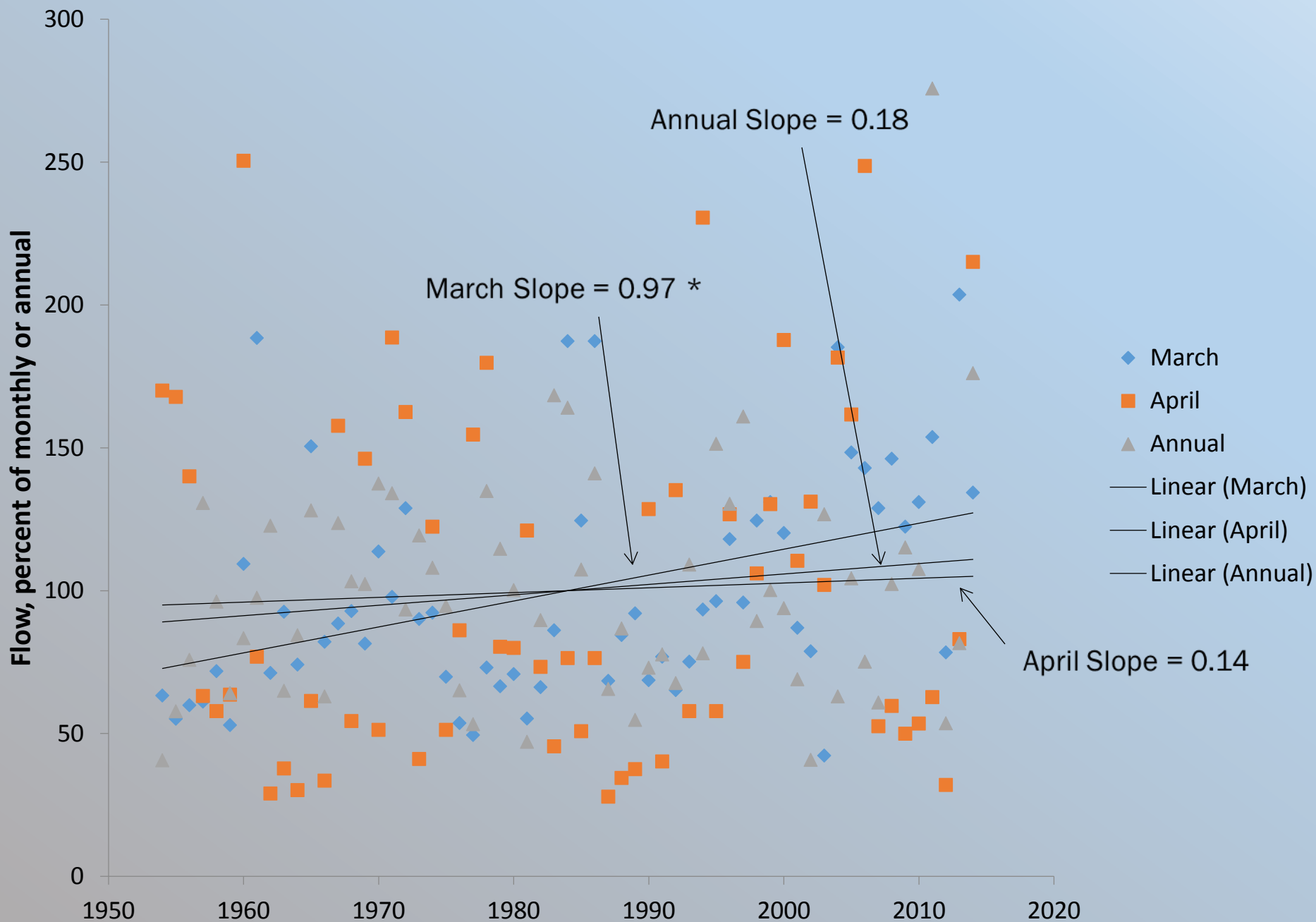
Big Thompson R Moraine Park Percent Change in Flow



Joe Wright Creek Percent Change in Flow



Colo. R at Baker Gulch Percent Change in Flow

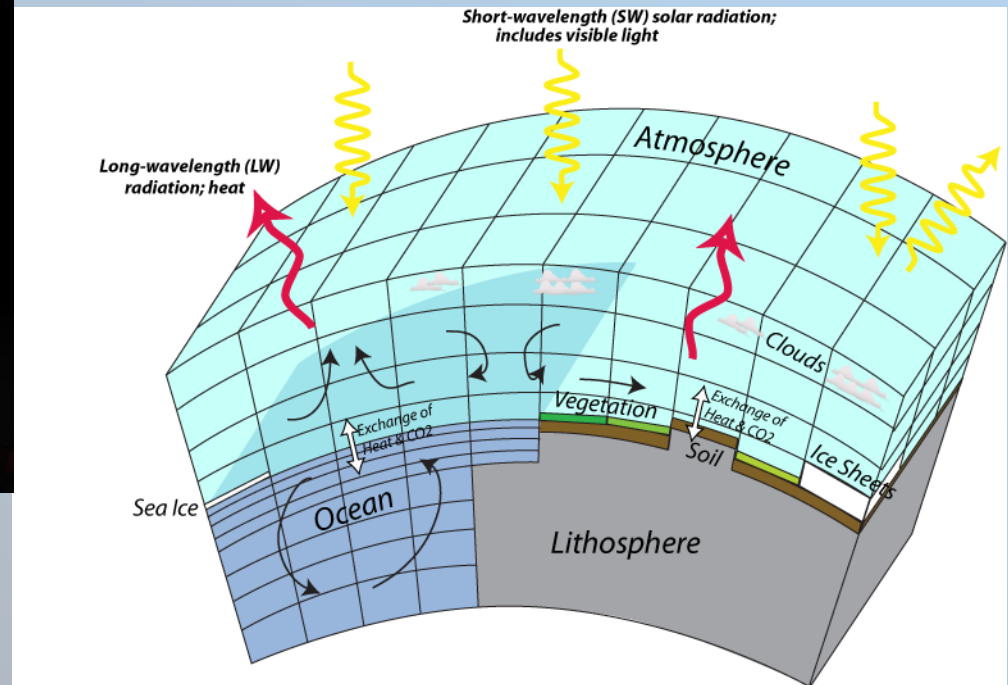


Explaining the trends

- So it appears that during March and early April we are seeing an increased tendency for snow to melt and turn into runoff, compared with earlier years.

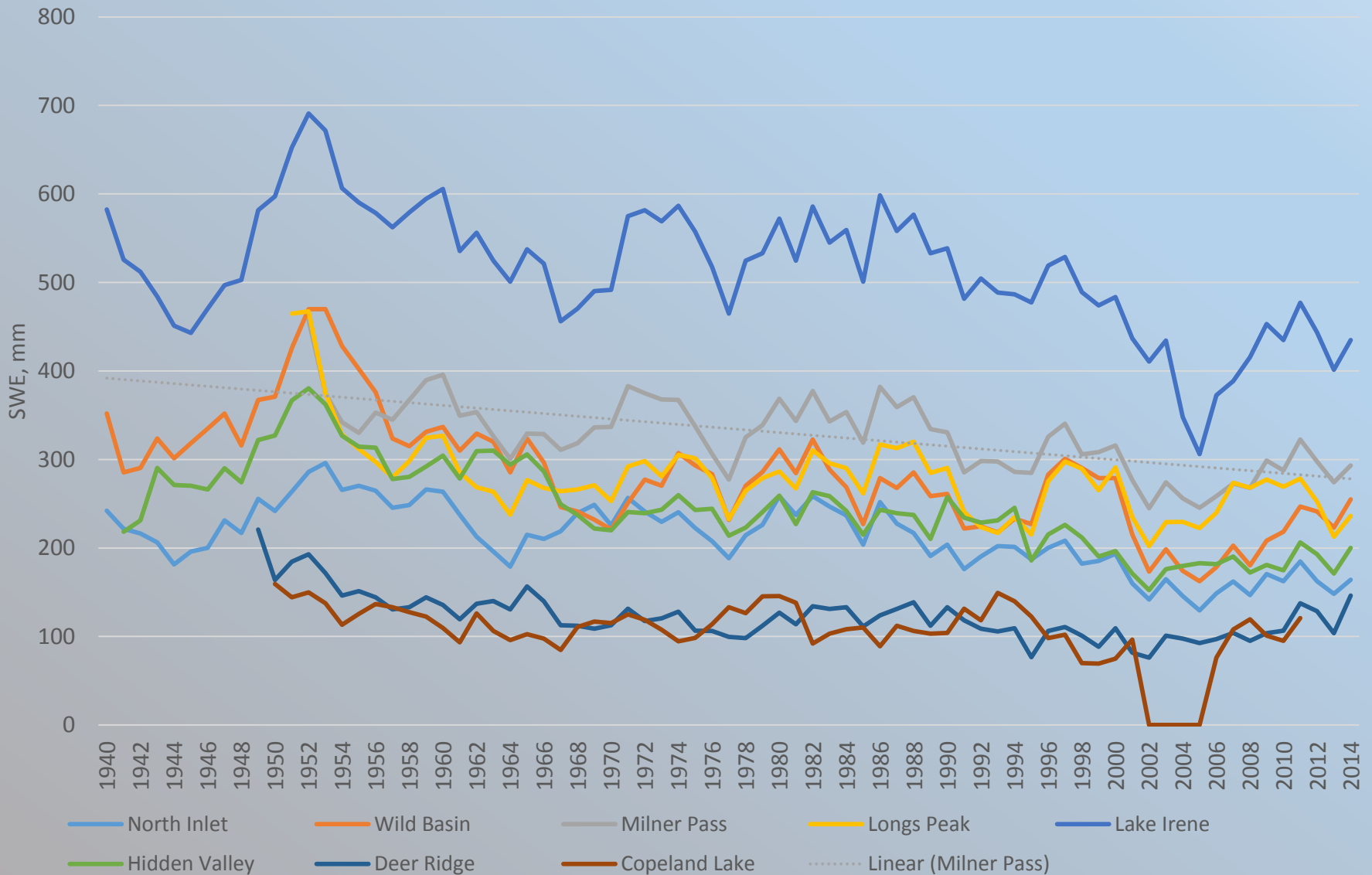


What does all this mean for the future?

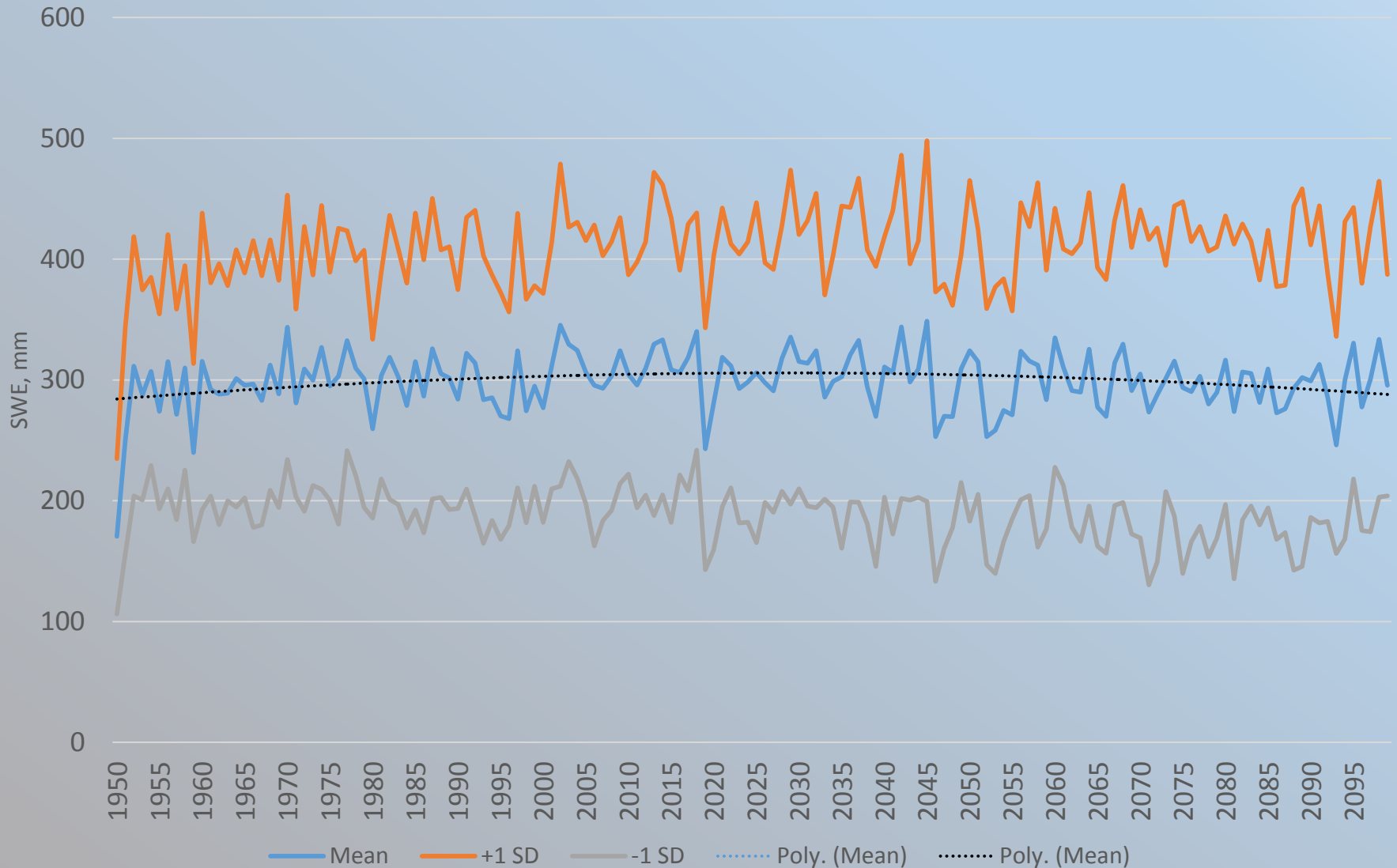


Schematic of a typical General Circulation Model

Trends in April 1 SWE at Snow Courses (5-year moving average)

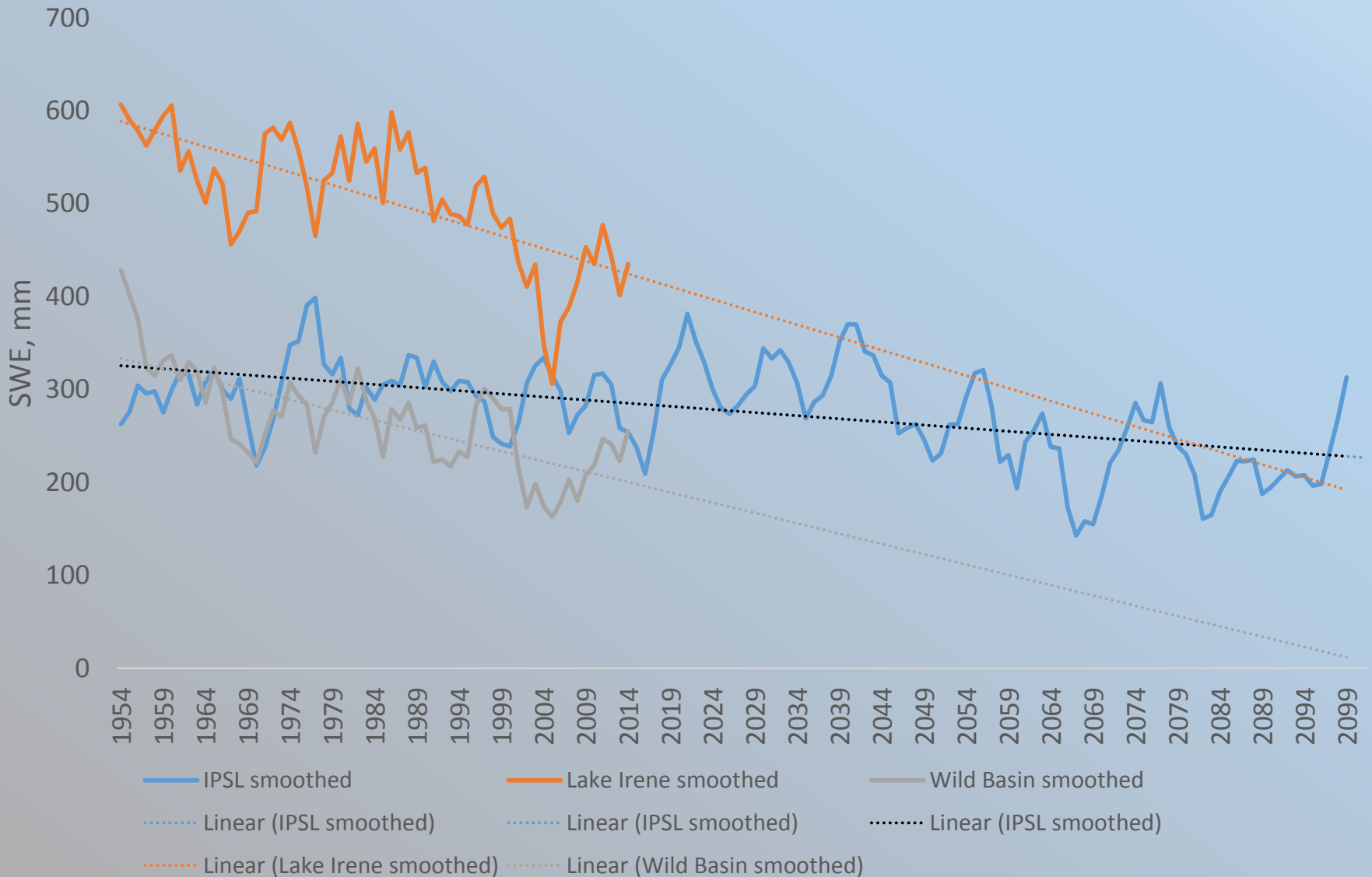


Projected April 1 SWE with +1 and -1 SD, Averaged Results of CMIP5 Climate and Hydro Models

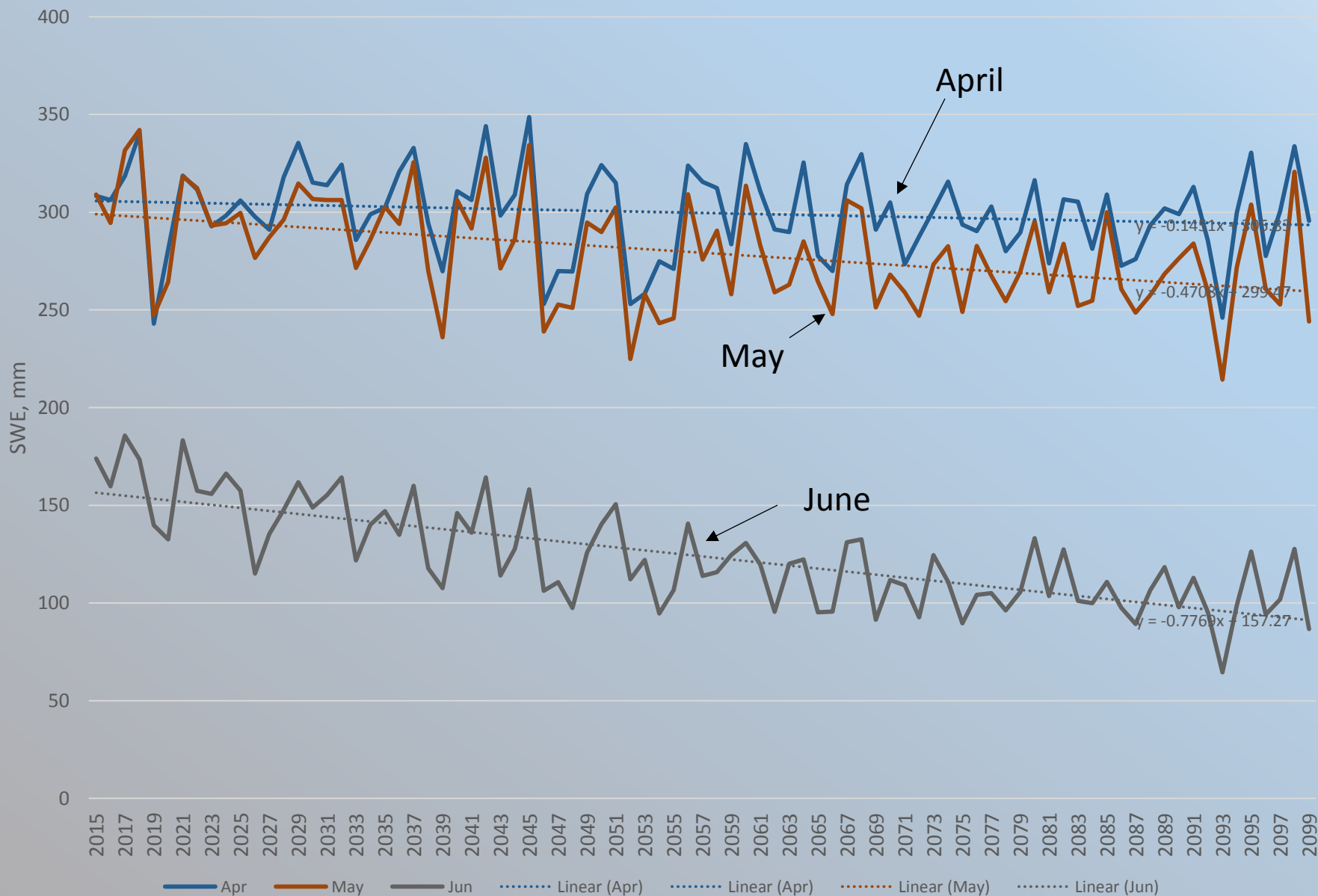


Observed and Simulated Trends in April 1 SWE

Single Model: IPSL



Smoothed Mean Model Projections of SWE for 3 Months



Conclusions

- Snow courses and SNOTELS show decreasing trends in SWE on specific dates, especially Apr 1 and May 1, as well as in peak SWE.
- Higher elevation sites are not immune.
- Snow is still falling at consistent rates.
- Warmer spring weather is causing increases in melt, especially during March and early April.
- Observed trends in SWE are declining more steeply than climate model projections would suggest.
- Declining trends in SWE are likely to continue.

